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RUDIMENTARY TREATISE
ON THE
ART OF PAINTING ON GLASS
OR
GLASS-STAINING

COMPRISING
DIRECTIONS FOR PREPARING THE PIGMENTS, AND
FLUXES, FOR LAYING THEM UPON THE GLASS,
AND FOR FIRING OR BURNING, IN
THE COLOURS

FROM THE GERMAN OF
DR. M. A. GESSERT
AUTHOR OF "THE HISTORY OF GLASS-PAINTING"

TO WHICH IS ADDED
AN APPENDIX ON THE ART OF ENAMELLING, ETC.

EIGHTH EDITION



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RUDIMENTARY TREATISE
ON
THE ART OF PAINTING ON GLASS,
OR
GLASS-STAINING.

INTRODUCTION.

1. **THE** beautiful art of glass-painting is not only restored, in our day, to the perfect fulness of its ancient splendour, but also has acquired, through the giant strides of the science of chemistry, and the great progress latterly made in the arts of design, an amount of technical and æsthetical power, far exceeding whatever could formerly be called to its aid.

Notwithstanding this advantage, however, the art has not yet reached that wide state of diffusion which, from the exquisite effects it is capable of producing, it deserves, and which it attained in the olden time, even with its then more limited capabilities.

2. This circumscribed use of glass-painting can scarcely be accounted for by a comparison of the religious circumstances of our age with those of the past, or on the supposition that this art, confining itself exclusively to exhibition in sacred edifices, had therefore been lost among the

frivolous tastes which at present prevail. On the contrary, the works of the finest masters of the art have shown that the wonderful effects of glass-painting may be brought into use for other purposes than the service of the Church, and may be made to satisfy not less the worldly demands of our generation, than the more devotional feelings of the middle ages.

The obstacles which, on the revival of the art, have interposed to check its further extension, and therefore to diminish also the general demand for its productions, are much rather to be attributed to those in whose hands it rests, than to any thing properly belonging to itself; they originate, in fact, less in the art than with the artists.

3. One of the principal causes of the earlier decay of glass-painting was, that its rules being based so entirely upon empirical principles, the artists who practised it were accustomed to consider the knowledge they had acquired in the thorny path of tedious and long-continued experiment, as their most valuable personal property, forming at once the means of their subsistence, and the foundation of their future artistical fame. They therefore not only kept the information they had gained profoundly secret during their lives, but even carried it with them to their graves, in preference to leaving it behind them to be made use of by their scholars.

This easily intelligible, but not on that account the less reprehensible egotism,—this avarice for artistical monopoly, also operates in some measure to damp the speculative ardour of the present day, and constitutes, in fact, the primitive cause of the evil of which we complain.

On the other hand the most conducive element towards the full and free development of power generally, and particularly of artistical talent, is competition. It multiplies production, invites public judgment and comparison, and calls forth a laudable emulation, tending, in return, not only to promote the excellence of the works produced, but, by aiming at popularity, also to create an ever new demand for their increase and multiplication.

4. The directions which form the principal part of the following pages have already been published at different times, in earlier communications of the same author scattered through German scientific periodicals, but have now been collected, enlarged, improved, and remodelled into the present form, in the hope that their more general circulation may put into the possession of the many that information which was formerly jealously guarded by the initiated few, and thereby such a general interest may be promoted as cannot fail to be beneficial to the art.

• The recipes have been carefully selected, and their correctness and efficacy proved by many

years' practice; and it has been endeavoured to make them so easy of comprehension, that neither those unacquainted with chemistry shall fail in their preparation, nor those unpractised in the art go astray in their application.

5. In the classification of the pigments into Fused and Mixed Colours, (understanding by the first all those which are fused into a glaze together with the flux before laid on, and by the second all colouring bodies burnt into the glass without such previous process, whether requiring the help of a flux or not,) the theory given by the Author in his late work on the 'History of Glass Painting' has been adhered to. This division has the advantage of avoiding those errors which had their origin in the early homonymic of *flux*, for the oxide previously melted with the flux, and for the fluxing medium itself.

It is hoped that these few pages may be the means of prompting, not only artists by profession, but also amateurs, to such an increased and successful exercise of the art, as may tend to show forth its beauties and capabilities to the world in a more general and extended manner than heretofore.

CHAPTER I.

OF THE PIGMENTS AND FLUXES; AND THE METHODS OF PREPARING THEM.

6. GLASS PAINTING OR STAINING* may be defined to mean, the art of painting on transparent glass (either colourless or already coloured in the process of its manufacture) with vitrescible metallic colours, which are afterwards burnt into the surface of the glass on which they are laid, leaving it more or less transparent.

7. All colour used in glass-painting are oxides of metals, or other metallic combinations.

They may be divided into two principal classes—

1. Those whose colouring base, or the oxide, is laid upon the glass simply in its original combination with an earthy vehicle.

The words 'painting' and 'staining' seem to be used in English synonymously with reference to this art. The former of these has been adhered to throughout this work, not only because it is more in accordance with the German expression, but because it appears more calculated to secure to this species of decoration a place (which it decidedly deserves) among the fine arts; whereas, the word *staining* might simply mean the *colouring of glass*, without any reference to design.—Tz.

2. Those whose colouring base, or the oxide, must be made to adhere by the help of a glassy body,—namely, the flux.
8. The colours which require a flux may be divided again into—
 1. Those in which the oxide unchanged, but only *mixed* with the flux, is attached to the glass.
 2. Those in which the oxide requires to be vitrified, by previous *fusion* with the flux, before it is laid on the glass.

The last may be called *Fused Colours*, all others *Mixed Colours*.

9. The classification above given may be made clearer by the following explanatory remarks.

Glass-painting is distinguished especially from other illuminating processes, in that the colours and the foundation on which they are laid must, in this art, be fused together in the kiln.

Now, some few colours combine with the surface of the glass, at the temperature of fusion, without further previous preparation than the simple laying on; wherefore these give to the glass only a colouring cementation or stain.

Others, on the contrary, in consequence of their peculiar nature, can only be made to combine with the glass, by fusing them, upon its surface, into another thin sheet or layer of coloured glass.

This is done by means of the *flux*, a vitreous compound, which fuses more easily (*i. e.* at a

lower temperature) than the foundation, the glass plate.

10. The flux may be used in two ways. With some colours it may be simply mixed before they are laid on, so as to combine, at the temperature of fusion, with their oxides, and to unite these again with the surface of the glass; but in other cases the flux must, before painting, have entered into a chemical combination with the oxides, *i. e.* must have been fused together with them into what may be called a *Fused Colour*, which latter, after being pulverized, serves as a pigment.

This process is rendered necessary in consequence of the difficulty of fusion of certain oxides, which, in order to combine with the flux, and to acquire the intended shades of colour, require a greater degree of heat than could be made use of in burning the colours upon the glass, without endangering the success of the operation.

From this description of the nature of the colours and the manner of their combination with the glass, we will now pass on to the practical directions for their preparation and use; in assurance that the foregoing will not only prevent erroneous notions being formed of the nature of the different elements entering into the operations, but may tend to the perfect understanding and successful practice of the directions given.

Those for white and black pigments are given first, the others follow in order.

I. WHITE.—FUSED COLOUR. •

11. Two parts of bone glass,* with one part minium, or red lead, are to be^d mixed together and melted in a covered Hessian^y crucible placed in a wind furnace. The mixture is then to be poured out into a flat vessel containing pure cold water, and, when cooled, is to be ground with a glass muller on a table of thick sheet glass.

MIXED COLOURS.

12. One part of bones calcined to whiteness, with two parts of flux, ground together on a glass plate.

• *Flux.* Glass of lead (flint glass).†

13. One part white oxide of tin, with two parts of flux, ground as before.

Flux. Lead glass.

14. *Preparation of the oxide of tin.*—Melt in a covered crucible one part of pure tin cuttings. When in fusion, add two parts of nitre and stir well the mixture with an iron rod. The crucible is then to be again covered, placed in burning charcoal, and the mixture occasionally stirred as before from time to time, until it begins

* Made by fluxing together eight or ten parts of calcined bone^d (bone ash), and eight of red lead, with about 80 of white glass.

† German *Bleiglas*. This, however, contains more lead than exists in our English flint-glass: a recipe for it, in one of the German Encyclopedias, is 15 parts dross of lead, and 12 parts common glass frit. The ordinary flint-glass may be made to serve by adding minium to it, and trials will show the best proportions. See Art. 88.

to get white on the top. Continue the stirring a little longer, then pour the mass out of the crucible into an agate mortar and let it cool. It is then to be pulverized, boiled in water, and afterwards dried.

II. •BLACK.—•MIXED COLOURS.

15. Two parts oxide of copper (prepared by heating nitrate of copper to redness), and one part flux.

Flux. Equal parts of crystallized borax, minium, and pounded glass, are to be mixed and melted in a crucible for about an hour or an hour and a half, in a wind furnace, then to be poured in a vessel of water, afterwards dried, and powdered on a glass plate.

16. Some oxide of iron, or of manganese, added to the former, gives that brownish tone of colour which was so peculiar to the ancient glass-paintings.

17. One part black protoxide of iron, (prepared by mixing red oxide of iron with olive oil to a moist powder, and afterwards heating the mixture in a crucible till the oil is evaporated,) one part of protoxide of copper, (prepared by submitting green carbonate of copper to a red heat, and washing it in water,) and two and a quarter parts flux.

Flux. Two parts lead glass, ground to a

proper degree of fineness on a copper plate, or colour stone, with water, and one-fourth of a part gum-, rabie. The latter to be added after the pigment is mixed with the glass. All are then to be ground as delicately as possible together.

18. One part oxide of cobalt, one part oxide of manganese, one part copper ashes,* and one part iron scale from a smith's forge, mixed together and heated, at first gently, but afterwards with a very strong heat, until the mixture runs freely. It is then to be poured into water, and, when cold, pulverized, mixed with twelve parts of flux, and ground fine.

Flux. One part pure white sand, and three parts litharge, are to be melted together till they flow freely, and then poured out on to a warm marble plate, or into an iron mortar; when cold, to be pounded fine and washed out with water, in order to remove any reduced lead which may be present.

19. Two parts black protoxide of iron, with two and a quarter parts of the flux described in Art. 17, and treated in the same manner.

20. One part iron smithy scales, three parts oxide of copper, and four parts calcined antimony, treated as in No. 18, and ground with three parts of flux.

* An oxide or dross of copper of a coarse kind, known to the smelters.

Flux. One part of sand, and three parts litharge, treated as in No. 18, and ground fine with one-third borax. The borax must be prepared in the following manner: a crucible is to be half-filled with it, and put in burning charcoal until the borax becomes spongy, or is calcined. It is then to be thrown into another crucible and melted in a strong fire to a clear flowing mass, which is to be poured into cold water, and, when cold, ground fine.

21. One part of purple (see its preparation further on), three parts oxide of cobalt, three parts iron smithy scales, six parts calcined antimony, and three parts copper smalt,* treated as in No. 18, and mixed with three parts of flux.

Flux. One part sand, and two and three-quarter parts litharge, are to be treated as in No. 18, and ground fine with three-eighths of a part of borax prepared as above described.

22. Treat three parts oxide of cobalt, three parts oxide of copper, three parts iron smithy scales, and four parts antimony, with three parts of flux, as described in Nos. 18, 20, and 21. . . .

Flux. One part sand, two parts litharge, and one-fourth part borax, treated as described in No. 20.

23. Two parts black oxide of copper, with two .

Copper oxide fused with glass and ground.

and a quarter parts of the flux described in No. 17, and used in the same manner.

24. A beautiful blue-black may be obtained by adding a small part of oxide of cobalt to the pigments in either Nos. 17, 19, or 23.

25. A black inclining to brown is produced by a similar addition of oxide of manganese.

26. Dull or dead black, for distances, is procured from one part of copper smalt and one part crude antimony* calcined (but not so far as to lose its blackness), ground together. Or,

27. One part copper smalt, and one part uncalcined oxide of manganese, treated as before. Or,

28. One part purple, one part oxide of cobalt, and one part oxide of manganese, ground fine together.

III. RED.—FUSED COLOURS.

29. One part oxide of iron, (obtained by heating clean iron nails red-hot, dissolving them in nitric acid, evaporating the solution slowly by a gentle fire, and roasting the residuum,) three parts flux, (consisting of one part sand, one part litharge†

* The common ore of antimony; the sulphuret.

† *Note.*—It may be understood here, once for all, that where sand and litharge are used as flux, as directed in Arts. 32, 36, 40, and 73, both these ingredients must be pounded together, melted in a crucible by a strong fire, poured into an iron mortar,

and one-fourth part borax glass*), well fused together, until a glass rod, with which the mass is to be stirred, draws fine and clear threads from it; then the crucible, with its contents in it, is to be thrown into water, and when cool, the pigment may be separated, pulverized in an agate mortar, and ground fine on a glass plate.

30. One part oxide of manganese, with eight parts of flux (one drachm of sand, and three drachms litharge), melted together and treated as above.

MIXED COLOURS.

31. One part sulphate of iron, free from copper, or oxide of iron precipitated from the sulphate, more or less heated, with two to three parts flux, ground together, give all shades from a light red to a blueish violet.

Flux. Six parts white silicious sand washed and calcined, four to five parts yellow oxide of lead, and two to three parts sub-

pounded fine when cold, and finally washed out with water, before they are added to the pigment.

But where sand, litharge, and *borax glass* are indicated for flux, as in Nos. 12, 69, 78, and 84, the sand and litharge are, as above directed, to be melted and pulverized by themselves, but the borax glass is only to be ground with this latter powder, and *not again melted with it*.

This remark will save the trouble of repeating the same directions in the above-mentioned articles.

* German *Boraxglas*, fused borax.

oxide of bismuth (made from the nitrate) finely powdered, and intimately mixed in a porcelain mortar: the mass may then be thrown into a covered crucible previously brought to a red heat, and stirred frequently with a steel rod until it flows freely. It is afterwards to be poured into water, then dried, powdered, and passed through a fine sieve.

32. Common red is given by one part of sulphate of iron heated by a strong fire, washed four or six times in hot water, dried, and finely ground on a glass plate, with three parts of flux.

Flux. One drachm of sand, and three drachms of litharge.

33. In order to give a fixedness to the colcothar, or crocus martis, which otherwise is very fugitive, it is proper to calcine it with fine white sea-salt, previously brought to a half-glowing heat in a covered crucible: equal parts of each are then to be ground well together in an agate or glass mortar: a crucible is to be filled with the composition, and kept for two hours in an increasing fire till it is surrounded with burning coals on all sides; it may then be removed, the mass cooled, pounded perfectly fine, and washed three or four times with hot water, stirring it carefully each time with a glass tube, in order to wash the salt entirely away. When the water no longer takes

¹ Yellow or reddish oxide of iron.

a red tinge, it is to be poured carefully off, the mixture again washed with cold water, dried, and ground with one part of the before-mentioned flux for use. For greater certainty the sea-salt may, previous to using, be dissolved, filtered, and recovered by evaporation of the water. Lastly, it is particularly to be advised to employ in the whole process, crucibles which have not previously been used.

34. Equal parts of yellow oxide of iron (iron ochre), yellow oxide of lead or lead glass, glass of antimony, sulphuret of copper, and sulphuret of silver, ground fine together with water, and laid on the glass without the addition of any flux.

35. One part of silver which contains copper (as for example, that of which the German small coin is made), with two parts of raw antimony (sulphuret of antimony, the common ore), melted together, reduced to powder, and mixed with red oxide of iron or coleothar. This pigment also is used without flux, and is (as is the former) to be laid on in a tolerably thick layer, which will stain the surface of the glass red at the proper temperature of fusion. What remains on the surface afterwards may be removed with a spatula.

36. One part silver, two parts red antimony, and one part sulphur, melted till clear; and mixed, for use, with two parts flux.

Flux. One drachm sand, and two drachms litharge.

37. Two parts red oxide of iron, one part litharge, one part gum, one part lead glass, and six parts of best red chalk.

The lead glass is first to be ground as fine as possible on a glass table, then the litharge, the gum, and the oxide of iron are to be added; and after these are all properly mixed together, the pounded red chalk. The whole must now be gently ground and mixed in a tall glass, with as much water as will make it the consistence of thin syrup; say four or five ounces. If the operation takes place in summer, the glass is to be put in the sun; if in winter, in the warmth of a stove, and the fluid must be most carefully preserved from all dust, yet without preventing evaporation by close covering. This is best done by inverting a glass bell over it, on whose sides the moisture will collect and flow away. The fluid must remain still three days; all the thick matter will sink and adhere to the bottom of the glass, while the liquid shows itself above on the sides in transparent rings of a beautiful red colour. It is now to be carefully poured off, more water added, as before, and the operation repeated as long as any colour can be obtained from the sediment. The colour is then to be dried in a glass colour-dish by the help of a gentle heat (best by placing it in the sun), and carefully preserved. While it is yet in a fluid state or moist, it always appears more lively and clear than when quite dry. In the latter state

it is to be used like gamboge, but without grinding, which would destroy its transparency and beauty. If properly prepared and used, however, this colour excels in both these qualities the most beautiful red of the ancients.

38. Brick-red is given by one part oxide of iron, and twelve parts ochre yellow (prepared from one part oxide of iron, produced from the sulphate, and one part oxide of zinc), mixed with five parts flux.

Flux. One part sand, three parts minium, and one-eighth part calcined borax; finely ground, mixed, melted, and thrown into water, dried and pounded, as described in No. 31.

39. Flesh-red is obtained by melting sulphate of iron and alum, in a coarsely powdered state, and increasing the heat till the appearance of the desired colour. The residuum is to be washed with hot water, and one to two parts of flux added thereto.

Flux. Six parts white sand, washed and heated to redness, four parts yellow oxide of lead, one part borax glass, and one part salt-petre, treated as in Art. 31.

40. For dull or dark red, one part of prepared blood-stone* is to be pounded and ground on a glass plate, with three parts of flux.

Hematite. The kidney iron ore of Cumberland.

Flux. One drachm sand, and two drachms litharge.

41. Purple, gold-purple, purple of Cassius, is obtained by precipitation from a solution of chloride of gold, by means of a solution of proto-muriate of tin. It receives, according to the greater or less quantity of tin in the mixture, and the lower or higher degree of oxidation of the solution, either a beautiful red colour of various shades, as scarlet, carmine red, rose colour, flesh colour, &c., or a violet or brown.

It is to be mixed for use with four parts of flux.

**Flux.* One part of silica in powder (made by calcining the purest flint three or four times in a crucible, washing it every time in pure water, then powdering it in a porcelain mortar, and sifting it through a fine sieve), one and a quarter part borax glass, and five-eighths of a part minium, melted together, and finely powdered.

42. Dissolve one part of thin-beaten gold in nitro-muriatic acid, or aqua regia, pour the solution into a glass, and dilute it with fifteen parts rain-water. Throw in one and a half part of pure tin cuttings, which have been dissolved in muriatic acid, and allowed to get cool.* While this is being added to the gold solution, the liquor must

* Literally from the original; probably it is this quantity of the murate thus formed which is to be poured into the gold liquor.

be continually stirred. After the mixture has stood quietly a quarter of an hour, half a part of clear urine is to be added, and all well stirred together. In about two hours the supernatant fluid is to be poured from the purple pigment, which will be found precipitated, and which is to be well washed out. When perfectly dried, put it in a flat porcelain vessel, lay a piece of paper upon it, and place it on burning charcoal till the paper is charred.

The purple pigment must be used with twelve parts of flux.

Flux. One part sand, two parts litharge, and three-fourths of a part borax glass.

43. Dissolve gold * in aqua regia. If the gold has been alloyed with silver, the solution must be poured off from the chloride of silver, which separates itself. The precipitate must be washed with some distilled water, and this latter added to the solution, which must then, unfiltered, be evaporated by a moderate heat until a thick crystalline saline skin is formed, under which, by inclining the vessel to one side, only a little of the red solution will be found liquid. The mass is now allowed to get cool, whereby it becomes thoroughly hard; it must be dissolved without delay in ten times its weight of water, and filtered, by which a small quantity of reduced gold is left behind. In order to cleanse the filter, a small

* The German gold coins are alloyed with silver

quantity of water must be reserved out of the prescribed weight, and afterwards this must be added to the solution.

For the preparation of the tin liquor, the crystallized salt of tin* will answer very well; if it is moist, it must be dried by pressing it between unsized paper.† One part of the salt is to be dissolved in four parts of distilled water, the solution filtered, and used immediately after its preparation, as after a time it would become turbid by attracting oxygen from the atmosphere, and would deposit oxide of tin in a white powder.

Further, dissolve one part of gum-arabic in three parts of hot distilled water, and filter it through gray blotting paper, which must be of a loose texture, or the gummy fluid will not pass through it freely.

Having now prepared the three fluids in the above-mentioned manner, mix three ounces of distilled water with twenty-eight grains of the gum solution, stir it carefully, and introduce fourteen grains of the tin solution. Rinse out the vessel in which the latter was weighed with a little water; weigh twenty-three grains of the gold solution and add it to the previous mixture, rinsing out the vessel again, but this time, instead of clear water, a portion of the compounded mixture is to be used for the purpose. The

* The muriate.

† *Druckpapier*, printing paper, which in Germany is unsized

colour which arises during the mixing of the fluids is a fiery red brown, but changes when burnt in upon the glass into the most beautiful purple red.

The colour may possibly be somewhat altered by the action of the acid liberated by the formation of the purple precipitate in the fluid; but this is obviated by diluting it with twice its weight of water, dissolving ten grains of bi-carbonate of potash in the same, and then first mixing it with the above-mentioned mixture of the gum and tin solutions.

In order to separate the purple, whose precipitation is at present hindered by the gum, spirit of wine is to be added to the mixture until it appears very turbid: for this purpose, about double its weight of 75 per cent. spirit is necessary, if the bi-carbonate of potash has been added, otherwise three times the weight. In the course of an hour, if the mixture has been occasionally stirred during the time, the purple falls down in red-brown flakes, and the fluid remains clear, or at least very little coloured. This must then be decanted, some more spirit of wine poured over the precipitate, and the whole dropped into a filter. It must afterwards be gently pressed out between blotting paper, the precipitate removed, and ground in a rubbing dish or saucer, with weak 50 per cent. spirit of wine, to a thin pulp, which is to be heated* three minutes in a suitable vessel, and

* *Kochen*,—literally, boiled or cooked.

then poured into a cylindrical glass. This operation is to be repeated, and the gum will then be all removed except a little harmless remnant, which is essential to be done. Should the purple fall slowly from the last solution, and exhibit an inclination to re-dissolve, or form a clear red sheet tight upon the bottom, a little more strong spirit of wine must be added after the water is poured off, so that the purple may be made to coagulate to a thicker consistency, and the last portion of fluid afterwards filtered away. The precipitate must, as before, along with the filter, be pressed between blotting paper, taken off with a blunt knife, and dried in a porcelain dish, whereby it becomes much reduced in size, and takes a perfectly dull colour.

For use, the purple is to be levigated on a stone with water, until a clear deep-coloured thickish fluid is obtained. Two to six* parts of flux^{are} then to be added, the levigation continued, and afterwards the whole dried in a porcelain dish. It may then be made fit for the pencil with thickened oil of turpentine, like other glass-painting colours.

Flux. Eight parts white silicious sand, washed and calcined, four parts borax glass, one part saltpetre, and one part white chalk: treat as in Art. 31.

* For the reason of the indefinite proportions given here and in some other places, see Art. 88.

IV. BLUE.—FUSED COLOURS.

44. Three parts oxide of cobalt, prepared in the following manner. Clean, roasted cobalt ore (zaffre) is to be dissolved in pure diluted nitric acid, at a gentle heat, until the solution is saturated; add water, precipitate the oxide with carbonate of soda, and wash the precipitate with hot water. It is then to be dried, mixed with three times its weight of pure dry nitre, placed in a crucible, and ignited with live coals. When the slight decrepitation is over, the oxide of cobalt is to be heated to redness, washed out, and dried. Three parts of this must now be melted with two to five parts of flux (composed of* eight parts washed silicious sand, four to six parts borax glass, one to two parts nitre, and one part white chalk), melted in a strong fire for an hour and a half, and ground fine for use.

45. If the cobalt ore can only be obtained raw, and it becomes necessary to roast it, the best Spanish or Swedish must be chosen, which may be tried by solution in nitric acid, diluted with two-thirds of water. The ore which gives the finest red colour in the solution is the best for the purpose, and should be chosen for the preparation of the colour. In order to free it from arsenic, it must be laid on and surrounded with

A misprint in the original alters the meaning of this passage; but the sense given in the text is evidently the true one.

charcoal on all sides, and burnt until the arsenic is deposited in white crystals on the walls and stones around, and the cobalt has attained a more metallic state and lustre. This operation, however, it must be remarked, requires the greatest care and precaution, on account of the dangerous vapours which arise; and if a place is not properly set apart for it, it should be performed in the open air.

16. Another blue fused colour is given by one part oxide of cobalt, and four parts borax glass, melted by a strong fire for four hours. The difficulty of fusion of the cobalt requires that this colour should be ground, for use, with two parts of flux, obtained by melting together one part rock crystal, and one part borax glass, throwing them in water and grinding them fine.

47. For dark blue, mix intimately four parts king's smalt, and about two and a half parts minium, in a porcelain mortar: set the mixture in a glazed crucible in a very strong fire, until perfectly clear glassy threads of a beautiful azure blue can be drawn from the mass. It must then be taken out of the crucible with a hook, dropped into cold water, and afterwards dried and finely powdered for use.

The proportion of minium must be varied according to the variable fusibility of the smalt which is used.

48. One part black oxide of cobalt, six parts

powdered white glass, and two parts minium; then two parts nitre; treated as the foregoing.

49. One part king's blue is to be melted with three parts borax glass, pounded, and then ground with two parts of flux of the same kind, and treated in the same manner as No. 46.

50. Light blue is given by equal parts of best king's smalt, white glass (pounded in a bright iron or porcelain mortar and sifted), and minium, mixed and melted, as in No. 17.

51. Two parts zaffre, eight parts finely powdered white glass, six parts nitre, and six parts minium, mixed, melted, and ground, as the preceding.

MIXED COLOURS.

52. Let roasted cobalt (ore) stand quietly for two or three days in nitric acid, diluted with two-thirds of water, placing it from time to time in hot ashes. When the mixture has gradually become a clear and fine red colour, pour it very carefully off so as to avoid letting any of the sediment go over with it. To the latter may be added water and more nitric acid, to extract any more red colour which can be obtained from it. The several solutions are to be mixed together in a porcelain vessel.

To six parts of this red solution add two parts of the whitest sea salt, purified as previously

described, and when the latter is dissolved, pour the fluid from the sediment (which is useless) into a porcelain vessel, and set it in hot ashes. Let it evaporate some hours, and as often as new sediment is formed, pour the fluid carefully away. Continue the heating of the latter, and stir it well, especially when it begins to thicken, with a glass rod, until at last it changes into a granulous salt of the most beautiful blue colour. This salt also is to be left an hour or two on the hot ashes, and is then to be put in the open air for a few days until it becomes crimson red. It is then to be replaced in the ashes, when it becomes blue, and again, in the air, when it becomes red again, and this process is to be repeated until no more nitrous gas * is evolved when the salt is heated, and until a sample of it, placed in a small glass with a little water poured over it, becomes red in half an hour, without imparting its colour to the water. When this point is arrived at, wash the salt carefully out, dry the now deep red coloured pigment in a porcelain dish, in hot ashes, and bring it once more over glowing charcoal, where it changes into a beautiful constant blue.

One part of this is to be mixed for use with two and a half parts of flux.

Flux. One part rock crystal, and one part well fused borax glass, pounded together,

* *Salpeterminale, nitrous vapour.*

melted, thrown into water, powdered in an iron mortar, and ground fine on a glass plate.

V. YELLOW.—FUSED COLOURS.

53. Jouquil yellow is obtained by melting together one part antimonie acid, two parts of a calcined mixture of equal parts tin and lead, one part carbonate of soda, and twenty-four parts of flux, composed of one part white silicious sand, washed and calcined, and three parts minium.

54. For citron yellow, mix and melt together two parts sand and six parts litharge; pour the mass into an iron mortar, and afterwards pound it fine. Then mix with it one part oxide of silver, and one-fourth part antimony ore (antimony of commerce), and grind the whole well together; melt by a strong fire in a Hessian crucible; pour in cold water, and grind for use.

MIXED COLOURS.

55. Mix fine powdered antimony with one and a half times its weight of saltpetre, decrepitate the mass in a glowing crucible, and heat it to redness for a quarter of an hour; powder it when cold, and wash it with boiling water. The remaining white powder, which consists of the bi-antimoniate and bi-antimonite of potash, must be moderately heated in a crucible for an hour, with an equal or

from that to a double weight of minram, and mixed with equal parts of flux for use.

Flux. One part white silicious sand, washed and calcined, and three parts minium, ground together, and melted as in Art. 31.

56. Uronium ore must be broken to pieces and roasted, afterwards dissolved in nitric acid, the solution filtered, and the lead which may be present precipitated by dropping in sulphuric acid. The clear green solution must then be evaporated to dryness, and kept at a red heat until it is changed into a yellow saline mass. One part of the preparation so obtained is to be ground with three parts of flux.

Flux. Four parts minium, and one part flint powder, melted together and pulverized.

57. Cut one part of pure thin-beaten silver in pieces, and break one part raw antimony and one part of lump sulphur to powder. Cover the bottom of a crucible with these two last-mentioned substances, lay upon them a piece of the silver leaf, and repeat the operation till all is laid in. Place now the crucible in red-hot charcoal, and cover it with one piece of the same. As soon as the sulphur begins to burn, the mass is in fusion. It must then be thrown into clear water, dried, mixed with three parts of dark-burnt ochre, and pounded perfectly fine.

The pigment may be used without the addition of flux or gum, and laid, to the thickness of the

back of a knife, on the reverse side of the glass. The superfluous quantity may be brushed off after burring.

58. For a light yellow, proceed as in the former case, only using one part of ochre instead of three.

The portion of the yellow colour described in the last article, which may remain after the burning, may be used again for colouring matter.

59. The peculiar yellow of the ancient artists is obtained by the following process :

Melt two parts of good sulphuret of antimony with one part of silver tolerably free from copper ; stir the mass together and pour it in a metallic mortar, pulverize the resulting sulphuret of antimony and silver, when cold, in the same mortar, and preserve it in a stopped phial. From this one part is to be taken, levigated with water on a copper table to the finest consistence, and mixed with four to seven parts of yellow ochre, twice heated to redness and washed in water, according to the proposed lighter or darker shade of the colour. Lay on as in No. 57.

60. Chloride of silver, and three times its weight of burnt ferruginous clay (burnt clay out of a baking oven, previously pulverized and sifted), are to be levigated with water, and laid on as in Art. 57.

61. One part sulphuret of silver, one part glass of antimony, and one part burnt ochre, ground as

fine as possible and treated in the foregoing manner.

62. For orange, dissolve pure silver in pure nitric acid, and precipitate it by hanging a piece of polished tin or copper plate in the solution. The flocculent precipitate is to be gathered together, washed in warm water, and ground fine.

One part of this to be mixed with one to two parts of the red colour, No. 37.

63. One part of silver in powder, precipitated from the solution of nitrate by a piece of thin copper, must be washed in warm water, ground with one part red and one part yellow oxide of iron, and laid on as in No. 57.

VI. GREEN.—FUSED COLOURS.

64. One part green carbonate of copper, prepared by precipitating it from a solution of copper in nitric acid with carbonate of potash, and afterwards properly washing and drying the precipitate; four parts powdered white glass, and two parts minium, must be well mixed in a porcelain mortar, and exposed to a very strong fire in a glazed crucible, until threads drawn out appear perfectly clear. It must then be taken out of the crucible with a hook, thrown into water, dried and pulverized.

65. Four parts oxide of copper, one part of antimoniac acid, or antimoniate of potash, and six parts flux (composed of six parts sand, four parts

yellow oxide of lead, one part borax glass, and one part nitre), to be melted together and ground fine.

66. One part copper precipitate, (obtained by dissolving sulphate of copper in eight times its weight of boiling water, and precipitating the copper by keeping a piece of polished iron in the solution for twenty-four hours, washing the precipitate with hot water and drying it,) four parts pulverized white glass, and two parts minium, treated as in No. 64.

67. One part oxide of copper, ten parts antimoniate of potash, melted with thirty parts flux (viz. one part sand and three parts minium).

68. One part borate of copper, (obtained by dissolving pure sulphate of copper in water, and precipitating it with a solution of borate of soda, washing and drying the precipitate,) three parts white powdered glass, and one part minium, mixed and treated as in No. 64.

MIXED COLOURS.

69. Dissolve three parts pure oxide of cobalt in nitric acid, and two parts tin shavings in muriatic acid; both solutions are then to be thrown together into one glass, and precipitated with carbonate of potash. The precipitate must be collected on blotting paper, washed, dried, put in a muffle on a porcelain pot, and exposed for about

eight hours to a yellow heat, being frequently stirred in the mean time. When cold, one part of this green is to be mixed with four parts flux.

Flux. One part sand, two parts litharge, and one part borax glass.

70. Equal parts of chromate of potash, and sulphur, are to be mixed and melted together in a covered crucible. As soon as the mass flows quietly, it is to be poured off and freed from the liver of sulphur which will have formed, by well washing with boiling water, when the oxide remains as a beautiful green pigment. This is to be collected on a filter, dried and ground fine. One part of it may be mixed for use with three parts flux, laid on and burnt in.*

Flux. Four parts minium and one part flint powder, melted together to a perfectly transparent glass.

71. One part of pure yellow chromate of potash ground together with three parts fine powdered quartz, laid on and burnt in.

72. One part black oxide of manganese, and two parts cobalt or king's blue, mixed together and ground fine.

73. Two parts pure oxide of cobalt, ground with one part flux.

Flux. One drachm white sand, and two drachms litharge.

* There is a misplacement of words in the original here, which creates some confusion.

Nos. 72 and 73 serve for green distances.

VII. VIOLET.—FUSED COLOURS.

74. Calcine best oxide of manganese in a potter's kiln with an equal quantity of saltpetre; take one part of this, six parts white glass in powder, and two parts minium; mix and treat in the manner already explained, with the strongest melting fire.

75. One part calcined oxide of manganese, one part zaffre, ten parts white glass powder, and four parts minium, treated as before.

MIXED COLOURS.

76. Gold purple mixed with chloride of silver, in varying proportions as practice will direct. The latter must previously have been melted with ten times its weight of flux, prepared from three parts white quartz, washed and calcined, five parts calcined borax, and one part minium. The gold purple is to be mixed with this, and the whole ground together.

The gold purple may be precipitated in combination with the chloride of silver by the following process. Drop into a large quantity of water, first some solution of tin, then a little nitrate of silver, and lastly the gold solution, constantly stirring the mixture. The proper proportionate quantities of the three solutions must be ascertained by experiment. The precipitate must be

mixed with about an equal quantity, or rather more, of the flux.

Flux. Eight parts sand, four parts borax glass, one part nitre, and one part white chalk, treated as in No. 31.

77. Gold purple ground together with three parts blue colour, and oxide of cobalt or king's smalt. This mixture gives the most beautiful violet colour, which may be made to assume different shades according to the greater or less quantity of purple, and the lighter or darker blue used.

78. One part purple, and six parts flux, ground together, give dark violet.

Flux. One part sand, two parts litharge, and one-fourth of a part borax glass.

79. Mix pure gold purple after precipitation and washing, but without previously drying it, with some flux.

Flux. One part silicious sand, washed and calcined, and three parts minium, treated as in No. 31.

VIII. BROWN.—FUSED COLOURS.

80. One part oxide of manganese, and eight parts flux (from one drachm of sand, and three drachms of litharge melted together), pounded and ground fine.

81. One part oxide of manganese, one-fourth

part blue of No. 52, and eight parts of the foregoing flux, used in the same way.

82. Two parts gold yellow of No. 57, one part antimony, and three parts flux (prepared from one part sand, two parts lead, and one-fourth part borax, melted together), powdered and ground fine.

MIXED COLOURS.

83. Red oxide of iron, prepared by precipitation with carbonate of potash from pure sulphate of iron, and afterwards heating the precipitate to redness until it becomes a lively red colour.

Flux. A quantity of lead glass equal to that of the oxide, and some gum water, ground on a glass table.

84. Two parts oxide of iron, three parts oxide of manganese, and three parts gold yellow of No. 57, melted together, poured into water, and when cold, mixed with three parts flux.

Flux. One part sand, two parts litharge, and one-fourth part borax glass.

85. Red oxide of iron (hematite, red chalk, or natural iron rust), with oxide of manganese, or a small portion of sulphuret of antimony and silver, or some oxide of silver, treated as in No. 83, serve the same purpose.

86. Or, the sediment left in the preparation of the red colour may be laid on the glass without further preparation.

87. Lastly, seven parts gold yellow of No. 57 ground with one part oxide of manganese, without melting or adding any flux.

(No. 81 gives sepia: 82, a yellow-brown.)

GENERAL REMARKS UPON THE PREPARATION
OF THE PIGMENTS AND FLUXES.

88. As an essential addition to the foregoing, we may here give some few general directions respecting the preparation and combination of the pigments and fluxes, which could not well be inserted in the recipes themselves.

It is impossible to give any absolute or positive instructions for the proportionate quantities of the ingredients used in the pigments or fluxes. The determination of these must in a great measure be left to the trials and experience of the artist.

The same will apply also to the proportionate quantity of the flux to be used with the pigment, and to the quality of the flux also.

89. The materials of the colours, as well as of the fluxes, must be as good and as free from foreign ingredients as they can be obtained; otherwise disadvantageous consequences for the beauty and durability of the painting are to be feared.

90. When pigments, or fluxes, or both, are to be melted together, this must be done in strong Hessian crucibles, which are to be protected from

the action of the melting mass by covering them internally with a mixture of chalk in water. Or they may be glazed, which especially prevents the penetration of fused colours containing oxide of lead. To effect this latter object, the crucible is to be rinsed out with water, then covered on the inside with pulverized white glass, placed in the fire, and heated until the glaze adheres perfectly to its sides.

91. For the operation of fusion in Hessian crucibles, it is necessary to use an ordinary wind or air furnace, furnished with a dome or cover having a draught-pipe. The inside is to be covered everywhere with fire-clay, to a thickness of three inches, and in the cover must be a door, or at least an opening, filled up with a clay stopper, by which the interior may be accessible, in order to lift off the cover of the crucible and to stir its contents with a polished glass rod. Upon the grate of this furnace must be laid a pot of clay, and upon this the crucible, which must be covered with an earthenware lid.* It may then be surrounded with wood charcoal.

92. The ingredients of the pigments which are to be fused must previously, unless particularly directed otherwise, be ground to the finest powder on a thick glass plate with a glass muller, or, where specially indicated, upon a copper table with steel muller, and not generally upon marble,

Thonscherben,—literally, a pot of clay.

porcelain, or substances containing lime, for these, by the process of rubbing, are liable to give off a portion of their material. The ingredients must be intimately mixed: the crucible is first (unless otherwise specified) to be brought to a red heat gradually, and the mixture then placed in it, but never in greater quantity than will three parts fill it.

In like manner must the ingredients of the flux be treated, and also those of the pigments and fluxes which have to be melted together to form a fused colour, provided that nothing appear in the recipes to render another mode of treatment necessary for the particular case.

The crucible must then, as a general rule, be kept some time at a moderate red heat, which is afterwards to be increased till the mass is perfectly melted and runs freely, and till threads drawn from it with a polished steel rod appear pure and clear. It must then be poured into a dish of cold pure water, afterwards dried, pulverized, and treated according to the special directions.

93. The pigments and fluxes thus prepared are to be tested in the following manner. Place a spacious crucible in a furnace in an inclined position, and put in this strips of the same kind of glass which it is proposed to paint on, streaked with the colours which are to be used. These are to be exposed to a lively red heat in the crucible

until they become weak and begin to bend, when they must be laid to cool on the top of the furnace or in the ash-pit, and afterwards examined.

Should the edges of the painted parts appear as if the colours had overrun their bounds, this is a sign of the super-saturation of the pigment with flux, and the latter must accordingly be reduced in quantity till the appearance is removed; otherwise the whole success of a glass-painting might be destroyed, for such easily fusible colours are apt to blend together when laid near each other.

On the other hand, the dull appearance and rough feel of the colours betray a deficiency of flux, which must therefore be added in greater quantity.

94. The various shades and transitions of the principal colours may be obtained, not only by the directions as to the materials and treatment given in the special recipes, but in more frequent cases and much more comprehensively, by certain manipulations which will be hereafter mentioned in the description of the manner of laying the pigments on the glass.

95. Independently of the fluxes named in the foregoing recipes for each special pigment, there are others which may serve for every colour, or at the most require a trifling variation in the peculiar proportions of the quantities of their ingredients. These proportions depend principally upon the greater or less fusibility of the pigment, and will

be easily discovered by the practised artist. Such a flux, for example, is four parts minium and one part powdered silica; the latter obtained from the purest flint, free from calcareous specks, by heating it to redness three or four times in a crucible, throwing it every time into water, and afterwards pouring it in a mortar, and sifting it through a fine sieve. This powder is to be mixed as intimately as possible with the minium, melted in a covered crucible, stirring the mass frequently with a glass rod, until it is transformed into a perfectly transparent yellow glass, the silica being entirely dissolved, and threads, drawn by way of test from the mass, being perfectly clear. It is then to be pressed out in water, dried and powdered, sifted through a fine sieve, and kept in closed bottles.

Or one part rock crystal is to be pounded and melted by a strong fire, with one part of well-fused borax glass, and treated, when it shows the before-named signs of perfect fusion, in the foregoing manner.

Or one part powdered white glass and two parts minium may be prepared in the same way.

96. Besides the implements already named, the following are necessary for the manipulation of the processes for preparing the pigments and fluxes; namely,—coal-shovels, fire-hooks, crucible tongs, hooks of polished iron for drawing the

* A porcelain mortar is mentioned, but this must be an oversight. See Art. 92.

melted masses out of the crucibles, mortars of iron and porcelain, colour dishes, &c. of the same material or glass. spatulae of iron and wood, and other things which can always be obtained without much trouble or expense, or indeed may be supplied from common household utensils.

In the absence of a proper wind furnace, a common round stove, like those used for warming the German apartments, may easily be adapted to the purpose.

97. All vessels which come into immediate contact with the pigments or fluxes, especially those used for their preservation, mixing, fusion, &c., must be kept as clean as possible, and carefully freed from all refuse after every time of using, lest by an accidental mixing of heterogeneous ingredients the fruit of the labour should be lost. Great caution is especially necessary in employing crucibles which have been used before.

CHAPTER II.

OF THE PROCESS OF LAYING THE COLOURS ON THE GLASS.

98. THE manipulation of the process of laying the colours on the glass varies, in some measure, according to the different kinds of glass-painting, which therefore call for the first explanation.

Either the colours may be laid upon a single sheet of glass, upon which the whole figure with all its principal colours and intermediate tints are burned in (*Peinture en apprêt*): or,

The figure may be composed of various pieces of *pot metal* (glass already coloured in its manufacture), and only the outlines and shadows painted on, the glass pieces giving the colours for the peculiar places where they are inserted (*Mosaic glass painting*); or,

Both these methods may be combined in one and the same picture, by composing it

partly of pieces of coloured *pot metal* and partly of white and painted glass, fixed together.

PEINTURE EN APPRET.

99. For painting on a single sheet of glass, the following rules must be observed.

A pure white glass must be chosen for the purpose, free from air specks or bubbles, and especially difficult of fusion, as the whole labour would be lost if it were attempted to burn in the colours upon a ground which fused as easily as themselves. It is practicable, as the examples of the ancients show, to paint on what would appear the commonest glass with a good result, provided that it does not contain too much lead, and thereby become too easily fusible.

Before the operation of painting, the glass plate must be rubbed to a sufficient extent with pure lime, slaked by exposure to the air, in order to clean it perfectly. •

100. The ground or foundation must then be laid over the whole surface of the plate, which may be done in two different ways. Some artists simply dip a piece of clean linen cloth or a flat camel-hair pencil in oil of turpentine, and brush the pane of glass with it equally over its surface; while others give to the whole a thin clear ground of black glass-painting colour, in such manner as

not to destroy its transparency, but at most to give it the appearance of a dead ground glass. Both methods answer the purpose of covering the glass with a viscous surface, which takes the design and the colours better than a polished ground; the latter prepares the glass at the same time for the painting effects which are to be obtained upon it.

In both cases the ground which has been laid on must be most carefully levelled over and brought to as thin a coat as possible with a large hair pencil, and must be dried quickly, taking great care to preserve it from dust, &c.

291. Painting on one sheet requires only one pattern drawing or cartoon, which, however, may be used in two ways.

Either the glass sheet, grounded and dried as above directed, may be laid upon the drawing, and the outlines, as seen through the glass, traced lightly with a fine pencil, and with black or other glass colour corresponding to the ground;

Or the drawing may be placed reversed on the sheet, and all the outlines marked over with a steel or ivory style. If this latter method is used upon a ground of simple turpentine, the back of the drawing must previously be rubbed over with black-lead, so that the traced lines may appear dark on the light ground.

In both cases, the drawing, whether it is placed upon or under the glass, must, for the sake of

convenience, be fastened to it with pieces of wax at the four corners.

102. For properly carrying out the process of laying on the colours, a desk or easel is necessary, which should be capable of being placed in an inclined position by means of props, and should be formed by fixing a glass plate in a wooden frame, so that the light may pass through the painting. Sometimes during the progress of the work, the glass which is being painted may be removed from the easel and laid upon a sheet of white paper, in order better to show the effect of certain colours.

103. The vehicle with which the pigments are laid on is generally oil. Some artists use exclusively water, but this alone is an insufficient medium for binding the metallic bodies to the glass, particularly if, as in the case of fused colours, they are somewhat coarse in their nature, and require to be laid on in thick layers. They then easily loosen from the plate before the firing, and render the process of laying on much more difficult. It is an important advantage, that with oil the edges are more sharply defined, and the parts already painted may be again touched over when dry without danger of loosening the ground.

It must be understood that when it is wished to make use of water, the plate must either not be grounded at all, or only with a glass-painting colour worked up with water.

The most suitable kind of oil for the purpose is rectified oil of turpentine, somewhat thickened by standing, and to which a little oil of lavender is added. This preparation gives the mass the necessary degree of viscosity, and also prevents the colour on the palette from drying up and thickening too quickly.

The palette should be of thick sheet glass, ground rough by rubbing with a glass muller and fine sand.

104. Preparatory to mixing with oil for laying on, most colours which require a flux must (unless a different process is specially indicated) be ground fine in water with the flux, and again dried. But the fused colours, *i.e.* those in which the oxide has already been vitrified with the flux into the state of a transparent glass, should, for the purpose of laying on, only be coarsely granulated; for the finer these are ground, the more likely is their transparency and perfection to be impaired when burnt in.

Those pigments which are laid on in their simple combination with an earthy vehicle, and without flux, as, for example, the yellow and red colours prepared from silver, form an absolute exception to the use of oil, and must, for laying on, be stirred up with water to the consistence of a thick cream.

The first of these three kinds of pigments should, as a general rule, be laid on in a thin, the

two latter in a pasty, state. The depth of tone of the colour depends, with all three, upon the degree of thickness in which the pigments are laid upon the glass.

The laying on of the fused colours is accompanied with more difficulty than that of the other kinds. The latter are simply laid on with the pencil, in the same manner as with other kinds of painting, and the only care necessary is that the coat may be perfectly equal and regular, wherefore for large surfaces a wide smooth pencil or driver is usually employed. The colours prepared from silver must be treated differently, and laid on the glass at least to the thickness of the back of a knife.

But the fused colours must be brought upon the surfaces to be covered in the state of a thick flowing mass, moist enough to run, but consistent enough to lie upon the glass. For this purpose small portions must be laid on and spread out with a pencil or small spoon, and made to flow to the circumscribing outlines, by inclining the sheet in the proper directions. If any part of the surface thus covered is required to take a darker tone of colour, the plate must be kept for some time at an inclination in the corresponding direction, so that the colour may thus accumulate thicker on that part. By this process many gradations of tone may be obtained from one and the same pigment.

105. The remaining rules for the laying on of the pigments are those which principally result from the different methods of painting on one sheet, of which there are principally three.

Either the whole picture may be brought out in its outlines and shadows, on one side of the sheet, with black, brown, or gray colour, and illuminated with the proper colours in the proper places on the other side;

Or simply the manner of ordinary oil-painting may be adopted with the glass colours, and the picture treated as by an artist in oil;

Or, as is now most customary, both methods may be united, the artist making use of each in certain places, according to the requirements of the object he has in view.

For these three methods the following common rules will serve.

106. The shadows and dark-coloured outlines, and that which is called in oil 'under-painting,' should be drawn on the front side of the glass, or that which is turned towards the spectator.

The illuminating colours, especially the principal ones, should be laid on the back or reversed side.

Intermediate tints, and gradations by shading, should generally be placed on the front side, but sometimes, when they alternate with each other, necessarily must lie on both; as they cannot be

put in contact on one and the same side without danger of running into each other and making a false colour.

The silver yellow and red colours, before alluded to, must always be placed on the back or reverse side.

In some particular cases colours may be laid on corresponding places on both sides of the glass, in order to produce certain effects by the light falling through the two together. Thus, purple on one side and gold yellow on the other give a magnificent fiery scarlet: blue and yellow, according to their respective intensities, give different shades of green; the latter, again, with blue on the opposite side, serve for excellent distance colours. And finally, by the mixture of several colours, the most diversified intermediate tints may be obtained, so that glass-painting in its present state may be brought to assimilate with oil-painting in its power of producing varied effects.

107. In order to put a new tone of colour on a surface already marked with outlines, &c., it must first be dried by a gentle and equal heat (to avoid the warping of the glass), and again painted immediately after it has cooled. Or the black lines first laid on may be at once burnt in, and, where possible, with these any yellow shades also which may be required, after which the painting, then fixed, may be further worked upon without danger of damage. The residuum of the unfluxed yellow

colour may be removed after burning, and again used. This colour must never be put over any other, nor over dark shadows, unless these are previously burnt in, but always requires a carefully cleaned surface of glass to lie upon; otherwise it would combine with the flux of the under colour, whereby the early residuum would be fixed, and the transparency and beauty of the whole destroyed.

108. All pigments must be laid on somewhat darker than in other kinds of painting, as they lose in depth by burning.

When a pigment has overrun its outline, the superfluous quantity must be removed, when dry, with a knife.

By taking away the ground with a style of fine grained wood, pointed in front and smooth at the back (a tool used in etching), the most effective lights may be obtained.

Should the colours not appear quite dull and dry, but shining and greasy, after the drying of the picture, this is caused by the misuse of the oil, which is always dangerous to the beauty of the pigments in firing.

It is neither necessary nor advisable to allow more than one day for the drying of the colours; the burning in should be proceeded with at the expiration of the time named.

Lastly, during the work, the greatest cleanliness must be observed throughout, the pencil

and palette must be kept perfectly clean, and the painting preserved from dust, &c., for which reason it is not advisable to paint in a laboratory or melting-room, where the presence of vapour, dust, and impurities of many kinds cannot be avoided.

MOSAIC GLASS-PAINTING. 18

109. The before-mentioned rules for laying on the colours will apply also to the method of forming designs with coloured pieces of pot metal, or partly with these and partly with painted white glass. It remains to say something more in reference to the employment of the cartoons, and the cutting and arrangement of the glasses in this branch of the art, which, however, is but little practised, since the leaden bars in a picture calculated for a near view are detrimental to the effect.

Mosaic glass-painting requires two cartoons. One of these, a finished and coloured one, is used by the artist as a pattern, and serves to determine the arrangement of the pieces of glass according to their several colours, and the manner of introducing the leaden ribs to fasten them together, according to the outlines of the figures. Each piece of glass proposed to make part of the picture must be distinguished by a separate number.

The other cartoon, which consists only of the black outlines of the lead jointing, and whose

several parts are numbered to correspond with the first, is to be cut up in pieces according to the outlines, and the size of each piece diminished all round by one-half the thickness of the lead bar of the jointing, so that the pieces of glass may be exactly cut to the proper dimensions.

The cutting of the glass may either be done by the diamond, or by tracing the line of division with a red-hot iron, after having made a small incision at its commencement, or by cutting with scissors under water, which, however, is not a safe process.

110. With overlaid glass, *i. e.* pot metal of two several sheets or layers laid upon each other from the frit, as for example, red and white, blue and white, &c., it is possible to produce many effects of shading by removing more or less of the coloured glass sheet, according to the outline, by grinding with emery. Or the coloured sheet may be ground through to the white glass, and thus coloured ornaments may be given on white ground, especially for the representation of damasked materials. Also, the white parts thus exposed may have a colour given them at pleasure on the opposite side, in order to produce many kinds of effects, or to avoid the necessity of using many pieces when the introduction of another colour in that of the pot metal is indispensable for the effect required.

The coloured pot metal may be painted with

intermediate tints of its own principal colour, or even, in order to produce certain effects, may be covered on one of its surfaces with another colour. Thus, a fiery red may be obtained by covering a red overlaid glass on its white surface with the yellow silver colour, and burning it in, or a shade of green by a similar use of the same pigment on a blue overlaid glass. In these operations the widest latitude is left to the talent and practice of the artist.

CHAPTER III.

OF THE PROCESS OF FIRING, OR BURNING IN OF THE COLOURS; AND THE CONSTRUCTION OF THE KILN.

III. THE object kept constantly in view in the foregoing explanation of the processes of glass-painting, has been to bring the practice of this art into the reach of as many hands as possible; and therefore it has been especially endeavoured to point out, not only the most suitable, but also the shortest and easiest methods of operation, in order to show that the processes are much less costly and complicated than generally supposed, and to put the reader as much as possible in the position of being able to construct for himself the requisite apparatus.

This principle has been particularly adhered to, in the following description of the process of firing, and the construction of the necessary kiln; for it will be shown that the operation may be performed in any common kitchen, and that an ordinary fire-place may, with the aid of some fire-bricks, tiles, and iron rods, be made to suffice for the con-

struction of a furnace which shall answer perfectly the purpose intended.

The remaining necessary implements consist of a muffle, an iron charcoal-shovel, a pair of fire-tongs, tongs to extract the trial pieces, and a pot in which to dry the charcoal.

112. The muffle, if it cannot be obtained of cast iron or plumbago, may be made of burnt earthenware, and its size may be regulated according to circumstances. If of the latter material, it must, in order to stand fire well, be constructed of a mixture of two parts fire-clay and one part fine sand, and should be of an oblong four-cornered figure: for example, twelve inches long, ten inches wide, and five inches high. It must, however, be large enough to receive the largest of the sheets to be burnt, without their edges coming in contact with the sides of the muffle.

In the middle of one of the short sides there should be an opening five inches long and a quarter of an inch wide, for extracting the test pieces. The muffle is to be closed with a cover of the same material, having two round holes of about one inch and a half diameter, running out into two tubes about two inches and a half long.

113. To receive the muffle, a four-cornered kiln is to be built, whose interior dimensions should be four inches longer, and as much wider, than the muffle which is to be placed therein.

For this purpose fire-bricks are simply to be laid upon each other, but in such a manner that the wall turned towards the operator may contain an opening three inches high from the bottom and twelve inches wide, for the management of the firing. When it has reached the height of four inches all round, a perfectly horizontal bearing frame is to be formed by laying a pair of iron rods upon the long sides. Upon these the muffle is to be placed, in such manner that the test opening is turned towards the operator.

After the painted glass sheets are laid in the muffle, the walls of the kiln are to be built to such a height as to reach one inch above the tubes of the cover; in doing which, however, another opening three inches and a half wide and two inches high, corresponding to the test opening of the muffle, must again be left in the front wall, or that turned towards the operator.

Both openings of this wall of the muffle must be capable of being closed; the lower one, that of the ash-pit, with a stopper of iron plate filled with clay; the upper one, or the one corresponding to the test opening, with a stone. Each of these stoppers must fit exactly, and be of the same thickness as the wall.

114. The painted glass intended for firing must be laid in the muffle in the following manner. Sprinkle first of all well-burnt lime with water,

and dry it again, when slaked over the fire. Sift this powder through a coarse hair sieve, so as to cover the bottom of the muffle to the thickness of one inch. Carefully level over this layer (since otherwise the glass might become crooked in burning), and lay the sheets upon it near each other, but not so close as to come in contact either with each other or with the walls of the muffle. Then sift another thin layer of lime over them; lay a second set of the pieces of painted glass on the lime, and continue in this manner up to the middle of the muffle, where the opening is made for drawing out the tests. These consist of strips of glass about six or seven inches long and one inch wide, streaked with patterns of the colours which are to be burnt in. They are to be laid in the muffle like the sheets of painted glass, upon a layer of lime, and covered with it in the same manner; and they must be so placed that one end may reach to the middle of the muffle, while the other end projects half an inch out of the test opening before described, in order that they may be laid hold of with the tongs, and drawn out for examination.

After these are placed, the sheets of the painted glass and the layers of lime are to be alternated, as before, until all the glass is placed in, or until the muffle is full. If only one sheet is to be fired, the muffle must be filled with common instead of painted glass, as above directed, and the single

sheet to be operated upon must form one of the middle layers. After this the muffle must be closed in.

115. In the two tubes of the cover are to be placed pieces of the same kind of glass as is used to paint upon, five or six inches long and one inch wide; these may be called *watchers*; they are to be placed vertically, and in such a manner that their lower ends may stand on the sheet of lime next under the cover, and their upper ends may project about two inches out of the tubes.

After this, and after the test opening of the front wall is closed with its stopper, the firing may be commenced by strewing glowing charcoal over the hearth of the kiln and to some little distance up the sides, then filling all the interstices between the muffle and the walls of the kiln with charcoal up to the height of the muffle, and afterwards covering the latter in such manner that the *watchers* may project in sight. The whole of the fuel will then soon catch fire.

Proceed to lay across the walls of the kiln some iron bars, and upon these some fire-tiles, so as to cover the kiln as far as an opening in the centre, not quite one foot diameter.

It is here to be remarked, that when the muffle is new, or has not been employed for some time before, it will be safer to heat it to redness previously to using, which is to be done in the above-

described manner, exactly as if it contained glass, increasing the fire to a white heat, and allowing the muffle to cool of itself after the fire is removed. When it is quite cold, it may be used with safety.

It is particularly necessary to take care that the heat of the kiln during the process is raised equally on all sides of the muffle; and the fire must also be retained at a uniform glow by the continued addition of fresh fuel.

116. When the muffle reaches a dull red heat, when the *matchers* bend, and when the colours appear clear and perfectly fused upon the test strips (which must have been drawn out and laid upon the top of the kiln to cool slowly), all which customarily takes place about the sixth or seventh hour of the burning, the fire is to be removed by the hearth opening of the kiln, as quickly as possible, but yet with care not to shake or disturb the muffle; all the openings of the kiln must be stopped and luted, and the whole left to cool gradually, which will require between twenty-four and thirty-six hours.

The spare charcoal may be thrown into a pot of water and used again.

After the cooling, the glass sheets are to be taken out of the muffle, cleaned with a brush and lukewarm water, and carefully dried.

• 117. Should any parts require further painting, and consequently another firing, the pigments

must be mixed the second time with a greater quantity of flux, in order to render them more fusible than those previously burnt in.

Also, the heat of the second burning should be less than that used the first time.

CHAPTER IV

OF THE OPERATION OF FIXING TOGETHER OR LEADING MOSAIC GLASS.

118. This process is most customarily and properly left to the glazier, who also ought to cut out the pieces of glass. In order, however, to leave nothing wanting for those amateurs who may wish to make the whole of a specimen of the art their own, the following rules may be useful.

Common window lead of the glaziers, but of very small dimensions, is to be laid round one of the middle pieces forming the glass-painting, so as to hold it in the groove of one of its sides, while, in that of its other side, another piece is to be inserted. Continue this, constantly under the guidance of the cartoon, upon which the work may be laid, and working always from the centre of the picture outwards, soldering the several pieces of lead together during the process, by their ends of contact, which may be interlaid in the grooves at the corners where they join.

For this the soft or tin solder (consisting of tin

having so much lead melted with it that when bent it does but slightly crackle — commonly one part lead and three or four parts tin) is required, and a common glazier's soldering iron with a copper point should be used for applying it. After this is heated in a charcoal fire, it is to be rubbed in powdered sal-ammoniac and resin, and then on a piece of the solder, a portion of which will adhere to the copper and may be carried to the leaden bars. When the soldering is executed, it will be well to touch over the junctures with dark oil-colour, or still better with dilute sulphuric acid, in order to remove the bright metallic lustre, which might otherwise damage the effect of the painting.

APPENDIX.

On the General Nature of Enamel-Painting.

ENAMEL-PAINTING differs from all other kinds in the vehicle employed for the colours, that is, to hold the parts together, and bind them to the ground they are laid upon. This is glass or some vitreous body, which, being mixed with the colours, and fused, or melted, by means of heat, becomes fluid; and having incorporated with the colours in that state, forms, together with them, a hard mass when cold. It answers, therefore, the same end in this, as oil, gum-water, size, or varnish, in the other kinds of painting.

The glass or vitreous body applied to this purpose of mixing with the colours, in order to bind them to the grounds, is called a flux, and makes one principal class of the substances used in enamel-painting. When this flux is easily fusible, that is to say, melts with a less degree of heat, it is, in the style of those who work in enamel, said to be *soft*; and when it is reluctant to melt, and requires a greater degree of heat, it is called *hard*. These terms are as well applied to the matter of

the enamel grounds, and all other vitreous substances concerned, as to the fluxes. It is, in general, a perfection of the flux to be soft, or run easily into fusion. But the great point, with respect to this particular, is, that when several mixtures of colours and fluxes are used at the same time, they should all correspond to each other in the degree of this quality; otherwise some would be rendered too fluid, and perhaps run the matter of the enamel ground into fusion, and mix with it, while others remained solid and insufficiently fused themselves. It is always necessary, likewise, that the enamel of the ground should be considerably harder than the mixtures for the colours; for if they both melt with the same degree of heat, they will necessarily run together.

It being requisite that the body painted in enamel should undergo a heat sufficient to melt soft glass, the matter of such body can only be gold, silver, copper, porcelain, or China-ware, hard glass, and earthenware. And where the metals are used, if the painting be of the nature of a picture, or demand a variety of colours, it is necessary that a ground of white, or some other colour, should be laid on the metal; the body of which ground must necessarily be of the same vitreous nature as the flux, but harder; as nothing else can endure so great a heat that is capable of incorporating with, and binding the matter of the white, or other colour, to the surface of the metal. The grounds, therefore, make another principal class of the substances used in enamel-painting.

The third class is the colours, which must likewise be bodies capable of suffering the heat of melted glass; and such as will either themselves be converted into glass, or kindly incorporate with it in a melted state. This of course confines the matter of such colours to metals, earths, or other mineral bodies; all vegetable and animal substances being calcined and analyzed with a greatly less degree of heat than the lowest sufficient to work enamel.

The fourth kind of substance is called the secondary vehicle; which is, some fluid body for laying on the ground, and working, with the pencil, the flux and colours when mixed together; since, as they form only a dry powder, they could not be used as paint without some such medium. But as this is to serve only for spreading and laying on the matter of the enamel, and not, like other vehicles, to assist in holding the colours together, and binding them to the ground (that being in this kind of painting the office of the flux), it is necessary that it should be some such substance as will evaporate and dry away without leaving any part behind: it would otherwise be heterogeneous matter with regard to the enamel, and consequently injurious to it. Essential oils have been, therefore, used for this purpose, as they have the quality of wholly drying away on the first approach of heat, together with a slight unctuousity, which renders them capable of making the matter of the enamel work properly with the pencil.

*On the Art of Gilding Enamel and Glass**by Burning.*

THERE are two methods of gilding enamel and glass, by burning or annealing: the one is the producing a cohesion of the gold with the glass or enamel by the intermediation of a flux; the other, by producing the like effect without any. But the principle is the same, nevertheless, in both; and is, in fact, no other than the causing the gold to adhere to the enamel or glass, in consequence of the fusion or approach to that state, either of the flux used, or the body of enamel or glass itself; by which the gold is cemented to such body.

The flux, when any is used, may be either simple glass of borax, or any of the preparations of fluxes powdered.

There are other differences likewise in the manner of this gilding, which respect the state of the gold; for it may be either used in the form of leaf gold, or in that of powder, either mechanically made, or by precipitation.

When leaf gold is employed for gilding enamel or glass in this way, without any flux, the enamel or glass may be moistened with a very weak solution of gum-arabic, and again dried. Being so prepared, it should be breathed upon till it becomes a little adhesive or sticky, and then it should be laid upon a leaf of gold; and if that be not sufficient to cover it, the remaining part must

be laid on others, and the work again breathed upon, if it appear dry before the whole surface be gilded. When the gold is thus united to the enamel or glass, by the cementing quality of the gum-arabic, which is used in order to keep it close and even to the body to be gilded, the work is ready for burning.

If the leaf gold be used for gilding enamel or glass with the aid of any flux, such flux, being finely levigated, should be tempered with a very weak solution of gum-arabic, and very thinly spread on the part of the work to be gilded; and when the gum-water is nearly dry, the leaf gold should be laid on the part thus prepared for it; or if the work be kept beyond the time, it must be breathed upon till it becomes sticky: the gold thus fixed on the work, it is in a state proper for burning.

The advantage in omitting to use any flux is the rendering the gold less prominent and uneven, with respect to the body gilded: which is in some cases material. But unless the ground, whether of enamel or glass, be very soft, it requires a strong heat to make the gold take hold of it; and this, in the case of enamel, endangers the ground, or any painting upon it; for if the degree of heat be not very nicely adjusted, the glass or enamel will run into too liquid a state in some instances, and in others not be softened sufficiently to cohere with the gold. The advantage of using a flux lies in avoiding both these inconveniences; and, particularly in the case of very

hard glass, the being certain that the gold will cake; which is, without this medium, sometimes dubious. But the flux lying under the gold prevents it necessarily from being so level with the surface, or having the same evenness, as when laid on the body itself without any intermedium.

Before we speak of the method of using the gold in powder for gilding, in this way, it is proper to mention the manner of preparing this powder; which may be best made in the following manner: Take any quantity of gold, and dissolve it in aqua regia thus: To 8 ounces of pure spirit of nitre add 2 ounces of sal-ammoniac, scraped perfectly clean, and powdered, which will convert the spirit of nitre to aqua regia. Dissolve, in 4 ounces of this aqua regia, put into a proper phial, half an ounce of purified gold, in the state it is to be had of the refiners, under the name of grain gold. In order to hasten this solution, the phial may be put into a gentle heat, where it must continue till the gold entirely disappears. Take, in the mean time, about the same quantity of aqua regia in another phial, and put into it filings or small bits of pure block-tin, so long as any brisk effervescence arises on the adding fresh quantities: but this must be done gradually, especially if the filings be used; otherwise the mixture will heat so much as to boil over, or break the phial. Drop then thirty or forty drops of the solution of the gold into a half-pint glass of water, and immediately after about fifteen or twenty drops of the solution of tin. The gold will be then precipitated in a red powder from the

solution in the aqua regia dropped into the water; and this operation must be repeated till the whole quantity of the solution is thus treated. When the last quantity of the red powder has been precipitated, pour off the clear fluid, and fill the glass with spring water: which, when the red powder has settled, must be poured off likewise. Hold then a sponge wet, but well squeezed, to the surface of the fluid remaining with the powder; and, when as much of the water as can be conveniently separated from it by that means, is drawn off, lay the powder on a marble or porphyry stone to dry, taking great care that it contracts no dust or foulness. When dissolved, make a precipitation of the gold, by putting into the solution slips of copper plate, which must be continued there till they no longer produce any effervescence in the fluid. These slips of copper being then taken out, and the gold adhering to them gently beaten off, the fluid must be poured off from the precipitate, and fresh water put in its place, which must be renewed, in like manner, several times, till the salt formed by the copper and aqua regia is entirely washed from the gold; which, being dried, will be ready for use.

The precipitation may otherwise be made by adding a solution of Roman vitriol, or of copperas, or common green vitriol, to the solution of gold, in the following manner: Take a solution of gold in aqua regia, prepared as above directed; and add to it gradually a solution of green vitriol or copperas in water, until no further precipitation

of the gold is made by the addition of a fresh quantity. The solution of the copperas may be made by putting one drachm of it powdered into an ounce of water, and shaking them till they appear to be dissolved; after which the solution must stand, and the clear part be poured off from the sediment, if any be found. The fluid must be poured off from the precipitated gold as soon as it is perfectly subsided, and the precipitation must be well washed by pouring on it several successive quantities of water. Roman or blue vitriol may be employed for this purpose instead of the green, but it is somewhat dearer, and has no advantage over the other. The gold precipitate thus obtained is very bright and shining. A similar kind may be prepared by putting flat bars or plates of copper into the solution of the gold in aqua regia; but the precipitate is of a brown colour, without any lustre or shining appearance.

This method is more expeditious, as the precipitation is instantaneously made. In the present practice, the (*aurum fulminans*) fulminating gold, or precipitation by alkaline salts, is made by those who gild glass in the greatest perfection; and the volatile alkali is employed for the precipitation by the chemist, who prepares it for this purpose. But when this kind of precipitate is chosen, the use of any flux must be avoided, and a very considerable degree of heat applied.

Where it will not answer the trouble to prepare precipitated powders, that formed of leaf gold may be used in its place; but the precipitates

are more impalpable powders than can be obtained by any different method, and will take a finer burnish than any other kind when employed in this sort of gilding.

The manner of using the precipitates of gold in gilding of glass or enamel, except with respect to the *aurum fulminans*, may be varied two ways, as well as that of the leaf gold; viz. by adding to it or omitting any flux. The convenience of using flux is the same with that before mentioned, with the further advantage of rendering the gilding extremely durable, even to a degree of bearing to be scraped. But the disadvantages are greater; for not lying under the gold, as in the other case, but being mixed with it, the flux destroys the rich metaline look, and, what is still much worse, in many cases prevents its taking a burnish with the true lustre.

In which way soever the powder is used, it is to be tempered with the oil of spike, and worked as the enamel colours; and the quantity of flux, when any is used, may be a third of the weight of the gold. When the gold is thus laid on, the work is ready for burning; which operation must be performed in the same manner, excepting as regards the degrees of heat, as in the ordinary methods of gilding.

In cases where the glass is very hard, or where the opportunity of a strong heat cannot be conveniently obtained, the expedient of using a flux in the following manner may be adopted with great advantage.

Grind glass of borax to a fine powder, and having tempered it with oil of spike, lay it on the glass where the gilding is to be made. Burn then the glass with the degree of heat that will run the borax; and, when it is cold, apply the precipitate, or leaf gold, and burn it again, as in other cases.

In this manner the advantage of a flux may be gained, without the inconveniences before mentioned, and the gold will take a very gentle heat. It is, indeed, attended with double trouble and hazard; but in the case of using leaf gold, where a very good burnish may be wanted, this method will perhaps be found on the whole the most eligible.

The manner of proceeding for burning or annealing the work in this kind of gilding is the same with the treatment of the enamel or glass in the use of the colours, except that the pieces may either be put into the muffles, or collins; or, in the case of the glass, if there be no painting, the operation may be performed in the naked fire.

After the work is burnt, if it be designed to be burnished, a proper lustre may be given to it by rubbing the gilded part with a dog's tooth, or with a fine agate, or iron burnishers.

*On the Taking of Mezzotinto Prints on Glass, and
Painting upon them with Oil, Water, or Varnish
Colours.*

THE painting on glass by means of mezzotinto prints is performed by transferring the ink of the print to the surface of the glass, and thus having obtained a drawing, colouring it by proper pigments tempered with oil, varnish, or oil of a vehicle. This transferring the ink from the print to the glass is effected by cementing the face of the print to the surface of the glass by means of some glutinous body which will not dissolve in water, and then destroying the texture of the paper by water, so that it may be rubbed entirely off from the cement upon the glass,—leaving, at the same time, the whole of the ink of the print upon the cement and glass, in the same manner as if the original impression had been made there.

The particular method of performing this is as follows :

Procure a piece of the best crown glass as near as possible in size to the print to be taken off, and varnish it thinly over with turpentine, rendered a little more fluid by the addition of oil of turpentine. Lay the print then on the glass, beginning at one end, and pressing it gently down in every part in proceeding to the other. This is requisite to prevent any vesicles of air being formed in the laying it on, by the paper touching the cement unequally in different parts; and to

settle the whole more closely to the glass; it is well to pass over it a wooden roller of about the diameter of two inches. Dry then the glass, with the print thus laid upon it, at the first, till the turpentine becomes perfectly hard, and afterwards moisten the paper well with water, until it is thoroughly soaked. After this, rub off the paper entirely from the cement, by gently rolling it under the finger, and let it dry without any heat: the impression of the print will be found perfect on the glass, and may be painted over with either oil or varnish colours.

The choice and treatment of the colours for painting in this way upon glass, in either oil or varnish, may be the same as for any other methods; and it is therefore needless to enumerate any further particulars

On the Devices employed for the more easily obtaining a just Outline in making Designs from Nature; and on the various Methods of Off-tracing, Calking, and Reducing Pictures, Prints, or Drawings.

THE drawing accurately and readily after nature, and depicted representations, by the unassisted hand and eye, requires greater practice and command of pencil than fall to the share of many, who nevertheless may not want abilities to colour or shade a picture or drawing when a proper outline

sketch is previously procured. The convenience of quicker despatch is moreover a matter of importance even to those who are most expert in this art. On these accounts, various means have been devised to lead and direct the eye or hand, in forming just outlines of the principal objects which compose the design. These means consist of several methods, founded on different principles.

In the drawing after nature, the interposing a transparent plane is commonly practised; through which plane the objects being seen from a fixed point of view, the outlines of their parts are traced upon it by chalk or some kind of crayon; or such transparent body is divided into squares, through which the objects being viewed, the eye may be enabled to form and dispose them with more certainty, on a paper or other proper ground, divided into a similar number of squares; or some reflected image is obtained by means of a camera obscura, which affords an opportunity both of drawing the figure, and imitating the natural colour of the objects. These are the devices employed for drawing after nature; but where pictures, prints, or drawings are to be copied, various methods are adopted. The most common method is by *off-tracing*, as it is called, which is the laying some transparent substance over the picture, print, or drawing, and passing over the outlines of the principal parts with a pencil or crayon, which delineation is to be afterwards transferred from this transparent body to the ground intended for the painting or drawing. The

second method, which is indeed only another kind of off-tracing, practised sometimes in the case of prints and drawings, is effected by laying the originals on the ground of paper or vellum designed for the copy, the back of the original being smeared with black, or with vermillion mixed with a little butter; or a paper so prepared being laid between the original and copy, and tracing over the principal parts of the design with a needle or some other such like instrument, by which means an outline sketch of it will be formed on the ground of the copy. This method is called *calking*, and is performed also in another way, by puncturing or pricking the original print or drawing, and producing an outline on a new ground, by transmitting a coloured powder through the punctured holes. The third is by dissolving part of the printing ink by means of soap, and impressing it on a fresh ground in that state. Another method much practised is the using squares in the manner above spoken of, in the expedients for drawing after nature, except that here they are to be laid upon the picture. This method is likewise applied to the more certain copying of pictures or drawings, where the new design is to differ in magnitude from the original, in which case it is called *reduction*. For this last purpose there is likewise another method employed, by means of a machine hereafter described for off-tracing, and by which, after drawing over the lines of the original, the new sketch may be made greater or less.

The particular manner of using the transparent plane for taking designs from nature is, by framing a piece of tiffany or fine lawn, of the size of the picture or drawing intended, and fixing it so that the whole view of what is to be painted may be seen through it; a sight-board, that is, a flat piece of wood, with a hole in it, being placed parallel to the tiffany or lawn, in such manner that the eye may command the whole view through it, at the same time that the hand may reach with convenience to draw upon it. The outlines of the object, as they appear through the hole in the sight-board, must then be traced out, on the tiffany or lawn, by a crayon formed of white or red chalk, charcoal, or any proper substance, by which means a sketch of the design will be produced. In order to form a more complete drawing from this crude sketch on paper or vellum, the tiffany or lawn containing it must be carefully laid on such paper or vellum in an horizontal position, and, being well fixed down upon it, must be struck with some flat body in every part, by which means the chalk or matter of the crayon will be transferred from the old to the new ground, and produce the same delineation of the object upon it as was before on the other. The impression thus made on the new ground should be then over-traced with a black-lead pencil, and afterwards corrected, if there be occasion, from the natural view through the sight-board; and this paper or vellum will then contain a proper outline drawing, if the design be intended for a painting in water colours. But when

this method is pursued with a view to a painting in oil, the tiffany or lawn, after the sketch is drawn, must be laid upon the ground of the intended picture, and proceeded with in the same manner as with the vellum or paper; only, in this case, the over-tracing must be made with some kind of crayon instead of the black-lead pencil.

It is advised by some to use paper made transparent by means of oil of turpentine, instead of the tiffany and lawn; but the use of it is only practicable in this way in a darkened room or other confined place, and the paper thus prepared does not become transparent enough, even then, to show minute or remote objects so distinctly as is necessary. If, however, any choose to use it, the usual preparation of the paper is, only to brush it several times over with oil of turpentine, and to suffer it to dry. The transparency will be much improved if a third of nut or poppy oil be added to the oil of turpentine; or otherwise a little crude turpentine or colourless varnish; any of which will render the oil of turpentine more efficacious for this purpose, and save the trouble and expense of rubbing the paper so often over as is otherwise necessary. The paper employed for this purpose should be that called fan-paper, or, if that cannot be procured, fine post paper may be substituted; and where the design is too large to be contained in one sheet, several may be joined together, by laying the edges of the sheets a very little over each other, and cementing them by using glass glue, which, if neatly done, will only slightly

affect the transparency in the joints. When the original sketch is made on transparent paper, the tracing or drawing may be performed by a black-lead pencil, instead of crayon, which renders the drawing much more perfect and durable; and, being thus completed, it may be used for off-tracing the sketch on any ground intended for a painting in either oil or water. If it be intended for a picture in oil colours, the back of the paper may be smeared with pounded black-lead, charcoal dust, or any powdered crayon; or, what is much better, vermilion mixed with just so much butter as will make it adhere to the paper. It must then be laid on the ground of the picture, and over-traced by a copper or iron stiff, or blunted needle, which will make an impression of the sketch on the ground by means of the colour on the back of the paper; or another paper may be coloured, with the black-lead or vermilion, instead of the back of the transparent paper, and being laid between that and the ground, will answer the same end. The means are no way different where the sketch is to be transmitted to paper instead of oil. But in colouring the back of the transparent paper, or that interposed where any such is used, care should be taken that the colour be so wiped off as not to smear the ground, or produce any effect, except where compressed by the instrument in the over-tracing; and this indeed should be regarded to a certain degree even with the oil ground. Where the sketch is large, and made on several sheets of paper, it is convenient to have weights

to place on the four corners of the conjoined sheets, to keep them even and steady on the ground. They are best formed of square pieces of lead with handles, and may be about two or three pounds weight each. †

The sketch on transparent paper may be otherwise transmitted to any ground by puncturing it with holes made near each other in the lines of the drawing, and then fixing it on the ground, and dusting over it black-lead or any other coloured matter finely powdered, and tied up in a fine linen cloth. This dust passing through the holes of the pricked paper will delineate the sketch on the new ground, so that it may then be over-traced by any kind of pencil or crayon. Glass has been also used in the same way as the lawn or transparent paper, but its texture hinders it from being well managed with chalk, or any crayon or pencil. There is also another method, not commonly practised, by which a sketch might be well obtained by the use of glass. This is by drawing the outlines of the objects with black colour in drying oil, and when the sketch is finished, laying the paper intended to receive the copy gently, and without any rubbing or shifting, on the glass, having first moistened it with water; by which means the black paint will be transmitted to the paper, as the moisture exhales from it, and an impression made sufficiently exact for the purpose.

The manner of assisting the eye, in designing from nature by means of a plane divided into

squares, is, by drawing cross lines parallel to each other on tiffany or lawn framed, or on transparent paper, or glass. This may be done with common writing ink, or any other way that will render the lines visible; and the divided plane must be then placed before the sight-board in the same manner as was before directed for tracing the outlines. The ground on which the sketch is intended to be taken must be also formed into an equal number of squares; and the objects, being seen through the squares of the transparent plane, will by this means be much more easily disposed in their proper situation, and formed of a just magnitude, by placing them in the corresponding square of the ground, than where the eye had no such medium to compare and judge by. But though the above substances are most commonly used, there is a more simple and effectual way of doing this, which is, by making a frame of a proper size, and dividing the area which it forms into squares, by threads of a moderate thickness. In this way the objects to be drawn are consequently more within the power of the eye than when the most transparent body is used. The drawing by the assistance of squares, to those who have the least command of hand, is by much the most expedient way. But in order to render this or the other methods more commodiously practicable, where it is to be done in the open air, a portable machine should be made for supporting the frame of the transparent plane, and also the sight-board. This machine may be constructed by joining three

long legs together, in the manner of the surveyors' instruments, in a block, and fixing the frame, by means of a foot which will slide into the same box, that it may be raised higher or lower. The sight-board must have a foot likewise, by which it may be raised higher or lower; though this must not be fixed into the block, but into a sliding piece, which must pass through the block horizontally, so that the foot of the sight-board being fixed into it at right angles, the board may be brought nearer to or drawn further from the transparent plane at pleasure.

The second method used to facilitate the drawing after nature, namely, by the reflected image of the object, is performed by the camera obscura, of which a portable kind adapted to this purpose is commonly made by the opticians. It is needless, therefore, to give any description of these instruments, and the structure of them immediately explains the manner of their use on a very slight examination. Where they are not at hand, and a prospect through any particular window is desired to be taken, an occasional camera may be formed. This is to be done by boring a hole through the window-shutter at a convenient height, and putting one of the glasses, called the ox-eye, into the hole; when, all other light being shut out, except what passes through this hole, and a proper ground of paper or vellum, &c. being held at a due distance from the hole, the reflected image of the prospect will be formed upon the ground. If this ground be formed of paper, and fixed steady by a proper

frame, the image will appear very perfectly on the reverse of it, and the artist may stand at the back, and trace the outlines of the necessary parts with great convenience.

Though the taking views of nature by the camera has several conveniences, and seems very advantageous, there is one very material objection to its use. This is, that the shadows lose their force in the reflected image; and objects, by the refraction, are made to appear rounder, or different sometimes both in their magnitude and site, from what they really are; which being opposed to the truth of any drawing, almost wholly destroys the expedience there would be otherwise found in this manner.

The method of making sketches of outlines from pictures, prints, or drawing by off-tracing, is performed by a variety of methods. The most common, where the size of the painting does not forbid it, is to take a sheet of paper prepared by oil of turpentine, or the other means, as above directed for the taking views from nature; and, having fastened it even on the picture or print to be copied, to trace over the principal parts with a black-lead pencil. By this means an outline being obtained, it may be imparted to any other ground, in the manner before described, when the same kind of outline is formed by drawing after nature. Where larger pieces are to be copied, lawn and tiffany may be used, instead of the transparent paper; or several sheets of the paper may be joined together by means of isinglass glue; and when the

outline is traced by chalk, or other proper crayon the subsequent proceeding may be similar in this case, as above, where the same kind of outline is taken from nature. Goldbeaters'-ski and horn, as prepared in plates for lanterns, and also the tale or fossil isinglass, and dried hog's bladder, have been likewise applied to this purpose. But where horn or isinglass are used being rigid bodies that will not yield to impart an impression by retracing, they may be best treated in the manner above advised, in the case of glass when employed for taking views from nature, which is, by tracing the outlines with black in oil, and printing a new ground of paper with it.

Another common method of off-tracing, in the case of prints or drawings, is to fix them against a window or other hard transparent body placed in a strong light, in a perpendicular position, and to put a piece of paper, vellum, or any other body sufficiently transparent, before them, to perform the off-tracing, by the view which is thus given of the objects in the print or drawing.

The other method of off-tracing, called *calking*, which is sometimes practised in the case of prints and drawings, is performed by tracing on the print or drawing itself, instead of the transparent body laid over it, as in the other manner. The back of it must be previously prepared by rubbing it over with black-lead powdered, or other such matter; or a paper blacked on the under-side may be used, instead of blackening the print or drawing. By either of these methods an outline will

be made on any ground of vellum or paper laid under the print; and if several grounds of very thin paper be laid together under the print, with each a blackened paper over them, so many impressions may be made at one time. The same effect may be produced by puncturing or pricking out the proper outlines in the print or drawing, and then using it for imparting the sketch to another ground, with the black-lead powder, &c. in the manner above described in treating of the use of the oiled paper. When the print or drawing is thus prepared by puncturing, it may be employed for transmitting the sketch to any number of grounds.

The manner of using soap for taking off the impression of a print on a new ground is this: Smear the original over with the common soft soap, commix with water till it be of the consistence of a thin jelly, and then lay it even on the ground intended to receive the impression, which must be also previously moistened with water; after which, being covered with several other papers, the whole must be compressed, by passing a wooden roller over them, or by rubbing strongly on them with the calender-glass used for glazing linen, or by any similar means. The impression of the original will thus be imparted to the new ground, which must be first dried, and then carefully washed with a sponge and water to take off the soap. It has been said by some that this treatment will do very little injury to the original print; but, besides the impracticability of

ever thoroughly cleansing it from the soap, a part of the printing ink is taken from it, and a proportionable share of the effect of the original impression destroyed.

A method parallel to this is sometimes used with prints and drawings, which is by holding them up to the light, and tracing the proper outlines on the back with a black-lead pencil, or any kind of crayon, and then laying the traced side on a ground proper to receive the impression, going over them with a roller or calender-glass, in the same manner as when the impression is taken by means of soap. On the same principle, in the case of compartments, cylinders, or any other regular figures, where both sides are alike, when one half is drawn or traced, the other half may be procured by doubling the paper exactly in the place where the two halves should join, and then pressing or rolling over the outside of the sketched part. By this treatment a corresponding impression of the design will be made on the other side, and the whole sketch will be finished without the trouble of drawing or tracing out the second half.

The method of copying designs by the use of the squares, either in order to paint in equal magnitude, or with a view to reduction, is this: Divide the original into a convenient number of squares, by ruling lines across it with any kind of crayon, and then do the same on the ground in a corresponding manner. The squares on the new ground may be either increased, diminished

or made equal as to their size, with respect to those of the original, according to the intended proportion of the new piece. The principal use of the squares, in this case, is so much the same as when they are applied to the taking drawings from nature, that it is needless to dwell longer on them. It may be here stated, that to those who can draw at all, the use of the squares is much more advisable, as well as in drawing after nature, than any of the other methods; it is much more improving, and, on the whole, less troublesome, to make a correct sketch in that way than by any other.

The manner of reduction, or, if that be not necessary, of tracing out an outline, where the magnitude of the original is to be preserved, by the machine above mentioned, which was formerly called a *parallelogram*, and by some a *mathematical compass*, cannot be properly understood without an explanation of the construction of the instrument.

This instrument is composed of a board or table, with ten pieces of wood fixed upon it, in a moveable manner; and by such a construction, that when one is moved, the whole of the rest move also similarly, with respect to the directions, but under greater or less angles. The board or table may be of fir deal, and is usually made in the form of a parallelogram. The magnitude of it, as well as of the other parts of the machine, must be according to that of the pictures, &c. intended to be used for reducing. But for the sake of

giving the comparative proportions, it may be stated at three feet in length, and the breadth may be about a foot and a half. It must be planed very even, but should not be of too thin a substance, and it must be covered with cloth stretched even upon it, and fastened down to it. The ten pieces of wood must be forged like rulers used for writing; and in the proportion here taken, they may be a foot long, and about half an inch in breadth, and the fifth or sixth of an inch in thickness. They must be fastened to each other in such manner that every one must be crossed by another in the centre, and by two others at such distance from the centre as exactly divides the two half-lengths on each side of it; except the two which form the extremities, and can be only crossed in the centre and in the middle of one part, which, in each extremity, will be the part opposite to that so crossed in the other, as will immediately appear on the pieces being laid together in the position here directed. The fastening must be by pins or rivets, on which each piece may be turned with perfect freedom; and near each end of every piece must be made a hole or a female screw, into which a crayon, portercrayon, or pencil, may be fixed, either by, or without, a screw. At the ends of those pieces which make the extremities there must be a smaller hole for a pin to be passed through to fasten the conjoined pieces to the board. In order to the more commodiously fixing the several parts of the instrument to the board or table, it

may be proper to have female screws at the places of the table where the rulers are to be pinned down, according to the different applications of the instrument; and the pins for fastening the respective parts must, in this case, have male screws at their extremities, correspondent to the female screws in the table. By these directions, closely followed, the parts of the instrument may be completely formed, and put together.

Colouring or Washing Maps, Prints, &c.

THE colouring maps or other prints is performed either by spreading opaque colours so thinly on the subject that the full effect of the printing may appear under them, or by using transparent colours which stain the ground and dry away without leaving any opaque body: this last method is called *washing*.

The using opaque colours, or such as have a solid body, in this way on prints, depends entirely on the kind of vehicle used; for if the colour be so suspended by the vehicle that it can be spread equally, it may be applied to this purpose with success; and such as are very strong and bright, even though of the most opaque body, as vermilion, verditer, ultramarine, or turpeth mineral, will answer the end. The best method of doing this, is the using the isinglass size, prepared with sugar or honey, according to the following directions: Take three quarters of an ounce of gum-arabic, and a quarter

of an ounce of gum-senegal. Powder them, and then tie them up in a linen rag, leaving so much unfilled room in the bag as to admit its being flattened by the pressure of the hand. Having squeezed the bag till it is flat, put it into a quart of hot water, and there let it continue, moving it sometimes about, and stirring the water, for about twenty-four hours. The gums will then be dissolved, and the bag must be taken out. The fluid being divided into two parts, to one half of it add a quarter of an ounce of white sugar-candy powdered, and keep the other in its pure state.

The following method is the most advisable for the making the isinglass size: Take half an ounce of the beaten isinglass, and a pint and half of water. Boil them till the isinglass be wholly dissolved, and then strain the fluid, while hot, through a linen rag. Divide the size thus made into two parts, and to one of them add an equal measure of hot water, by which means a strong and weak size will be likewise obtained. This makes the colours of this sort work so freely that they may be diffused almost as easily as the transparent kinds, and with nearly as good effect. But it is proper in most cases to dilute the composition more for the washing of maps, and spreading the colour over large surfaces.

Besides the opaque, there are a number of colours which are semi-transparent, and yet have a body in a greater or less degree. These are carmine, bistre, and gall-stone, in the first degree, with lake and Prussian blue in the second; all

which may be treated in the same manner, but require very different proportion in the strength of the size.

The transparent colours should be preferred for this purpose to either of the other kinds, as their effect is better, and they require no preparation. The colours are, *for red*, red ink,—*for blue*, litmus,—*for green*, sap green and verdigris (in vinegar),—*for yellow*, gamboge, the yellow berry wash and turmeric wash,—*for purple*, the logwood wash and archil,—*for brown*, Spanish liquorice,—and *for black*, Indian ink. These require only to be dissolved in water, which should be more copiously added when employed for washing prints or colouring large grounds of any kind.

It must be carefully observed, in employing the opaque or semi-transparent colours, never to cover any parts so strongly as to prevent the distinct appearance of the shades of the printed design.

In the *illuminating* (as it is called) maps, as little peculiar in the manner is necessary as in the case of other prints; only the intent of colouring them being to distinguish the divisions of the maps with respect to countries, districts, &c., care must be taken not to lay the fluid colours on so copiously as to flow beyond the limits of what they are intended to cover. The rest depends on the so disposing of the variety of colours in different parts as to give them a strong and pleasing effect, which must depend more on fancy and good taste than on any rules. There is

indeed one thing in particular, which, it may be proper to remark, should be always avoided: it is the laying such colours as have any affinity or likeness close to each other; for by an error in this particular they will be rendered much less effectual with respect to the purpose they are to serve; as it is by such a disposition made more difficult to the eye to distinguish the limits and bounds they are intended to mark out. And moreover, for want of due apposition, the diversification of the colours is made less pleasing, when they are seen at a distance, and considered only with respect to their ornamental appearance. There is one other rule which is more especially necessary to be observed, though many think they are giving most perfection to their work when they most deviate from it: it is, the never using too strong and deep colours for this purpose, as they render the legible characters of the maps less distinct and perceptible. Such a practice is therefore repugnant in a certain degree to the principal intention of the maps, and moreover gives them a tawdry glaring appearance which is very inconsistent with good taste, one great principle of which is simplicity, and the avoiding a false and unmeaning showiness.

RUDIMENTARY ESSAY
ON THE
ART OF PAINTING ON GLASS

FROM THE GERMAN OF
EMANUEL OTTO FROMBERG

EIGHTH EDITION



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ON THE ART OF PAINTING ON GLASS

INTRODUCTION.

PAINTED windows are allowed to be the richest and most magnificent application of art to the interior decoration of monumental buildings. The brilliancy and liveliness of the colours of which glass is susceptible on account of its transparency will always secure to this kind of painting a distinguished rank among the arts. The dazzling combination of colours, which fills the observer with astonishment on account of their brilliancy, as well as on account of their variety, gives a peculiar character to painted windows which prevents them from falling into oblivion, even should they be neglected for a time. If we go back to the elementary condition of the art, the symmetrical arrangement of pieces of glass of various forms and colours, combined with more or less skill, they are by no means entitled to engage our attention in a higher degree than the lustre of gold, and the most lively colours of the richest decoration. Yet with what magical charm must they not attract our observation and excite our admiration, when painting invests form with these beautiful colours, and breathes life and soul into them!

• Painting on glass seems to have made a fresh start within the last few years. The favour with which the productions of this art have been universally received, promises it soon a new and brilliant career. But how has it happened that this species of painting, whose magical effects have been so justly appreciated, has been neglected for so long a time, after having for several centuries exercised the genius of artists, and been cultivated by them to the exclusion of almost every other?

• Painting on glass has, in fact, experienced a remarkable fate. In the periods of barbarism, when war and devastation had smothered the taste for the arts, it came into existence, and was never more flourishing than in those centuries of ignorance. At the period of the regeneration of science and the arts, when good taste and the love of what is beautiful and true to nature had begun to spread through Europe, its splendour seemed on the wane, and in process of time it became almost entirely extinct.

What, then, are the causes of so remarkable a decay? In the twelfth century, this art, which had been for a long time still in its infancy, seemed encouraged by the piety of the monks (among whom alone the wrecks of the sciences and of the secret arts were yet to be found) to make a vigorous attempt to release itself from the state of oppression into which it had fallen. But while the spirit was active and ready to soar, the means were wanting, and much time was spent in the choice of the proper mode of carrying it into practice. Many kinds of painting would have to be tried; and, at a time when taste had not yet been refined by long practice, and especially by the study of classical models, the preference would naturally be given to that kind of painting which was most capable of seducing the eye by the brilliancy of its colours. The combination of colours was the sole charm that painting could lay claim to; the merit of a beautiful outline, on the contrary, one which exhibited grace, purity, and correctness of form, was utterly neglected.

Hence the splendour of painted glass, and the almost universal admiration paid to it by those who felt themselves compelled to do so by the guardian genius of the art.

But in the succeeding centuries taste was cultivated. Art had less of the material, and found other facilities and other means of producing effect. She strove after effects of a much higher kind; and as genius endures with impatience the bridle of a difficult execution, the obstacles which the painting on glass presents to the expansion of thought would considerably diminish the favour that it had enjoyed in consequence of the liveliness of its colours. Oil-painting was soon called into existence by Jean de Bruges. This new form of the art, the imitation of nature, gained the victory over the one which had preceded it, and painting on glass was driven from its throne.

The consequent decline of the art was not, however, sudden and precipitate. The revolution which in the sixteenth century took place in the arts, was also not without its influence upon the progress of painting on glass. Its most beautiful works were produced at that time. The most celebrated men did not disdain to support it by their talent, and never at any time was it more deserving of honour. It had, however, attained the summit of its greatness, and was soon to become a spectacle of the most complete decay.

Many causes undoubtedly conspired against its further prosperity. To these, among others, belong the religious disturbances and the wars which followed the reign of Francis I.,

and the calamities that were brought on by subsequent disorders. But, above all, we must take into consideration the very strong prepossession in favour of oil-painting, awakened by the brilliant successes of its productions; and, moreover, the favour with which the art of engraving on copper, as well as all those arts which have drawing for their basis, were received. These arts shared among themselves the consideration that had been formerly given exclusively to painting on glass. Finally, we must bear in mind the singular patronage bestowed on oil-painting by those in power.

The various phases of the art of glass-painting clearly ascertain the mighty influences to which it must have yielded. The study of them offers to the inquirer matter for the most serious consideration. In the twelfth and thirteenth centuries, in the shadow of barbarism, if I may be allowed the expression, we see it making considerable progress. In the fourteenth and fifteenth centuries it bears unlimited sway over the arts. In the sixteenth century it becomes a rival to oil-painting, and, after an obstinate struggle, sinks into oblivion. All the old painted windows have something characteristic of the period to which they belong. The modifications which successively appeared in them offer to the archaeologist points of the deepest interest for observation and comparison, while they are at the same time the seals of their respective eras. These distinctive marks exist not merely in the painting, but also in the general conception of the entire work. We have only to cast our eyes upon a window of the twelfth and thirteenth centuries, and we shall discover in a truly remarkable manner the whole spirit of the Gothic monuments of that period. This kind of architecture, so rich in its ever alternating details, yet without any confusion, and regular in its monotony, successively presents that remarkable feature which we recognize alike in the entire structure and in each of its parts; and the reason of this lies in the fact, that the observer, before he can comprehend the numerous details, gradually perceives that they form an essentially harmonious whole. This peculiarity prevails in Gothic church windows to an extraordinary degree. When viewed at a certain distance, they present a magnificent decoration of the most lively colours, distributed in a manner worthy of the most skilful workers in mosaic. It is a rich carpet whose simple but graceful pattern is illuminated in alternate gradations of colours admirably combined. Upon a closer inspection, we obtain a complete view of the forms of the various ornaments which contribute to the general effect,

the naïveté of which makes us feel less regret at the imperfection of the execution.

Gothic painting borders on the mosaic, and we may go so far as to say that to this it owes its origin. Like the mosaic, its art was primarily limited almost exclusively to the symmetrical arrangement of pieces of glass of various colours. The art of drawing played here only a subordinate part; but, like the latter, it afterwards borrowed its forms from nature. In proportion as the taste for correct drawing was carried to perfection, the simple arrangement of glass lost its importance, and was finally eclipsed by the art of painting.

In the sixteenth and seventeenth centuries correct delineation completely gained the ascendancy in painted windows, and we find in these neither the effects of symmetry nor of the mosaic. It underwent a change in every particular to an historical kind of painting, of a much higher and more elaborate style, but which was no longer so rich and so brilliant: the sentiments of the soul gained at the expense of the impressions of the senses.

In the intervening centuries a transition took place from the one extreme to the other. At first we see the ground diversified with a thousand brilliant colours, on which, however, larger figures, drawn with greater skill, and after a pattern more or less understood, are occasionally to be met with, and occur as exceptions. In process of time these figures are surrounded with splendid borders or friezes, which are finally obliged to give way to architectural backgrounds and the imitation of the antique. These are the various forms under which the art of painting on glass was cultivated during a period of more than six hundred years. In the eighteenth century it seemed to be completely lost.

But is it destined to lie neglected because the reign of oil-painting will endure? Painting on glass cannot for a moment contend for the approbation of artists as the rival of the latter. The difficulty which attends the practice of it, and the necessity for the co-operation of chemistry in the productions of this kind of painting, leave its resources ever insufficient to enable it to vie with oil-painting, to which, on that account, it must unquestionably yield the pre-eminence. But if the artist who devotes himself to glass-painting is content to avail himself only of the legitimate resources of his art, if he does not strive after effect nor endeavour to pursue the path of oil-painting, we have not the slightest hesitation in asserting that painting on glass, considered as a monumental style of painting,

constitutes an art, inimitable in itself, capable of being executed with great spirit, and worthy of engaging the most distinguished talents.

But then the painter on glass must refrain from attempting to imitate oil-painting. On the contrary, he must acquire the conviction that, although these two arts have unquestionably a point of contact, they nevertheless possess sides extremely dissimilar. To these belong, in the first place, the proper modes of practising them respectively; secondly, the different conditions under which their effects are produced. Thus, for example, painting on glass, on account of the distance at which the picture is placed from the spectator, requires to be treated in a perfectly distinct manner. It excludes detail, which, on an opaque surface, is susceptible of great effect, but which, through the transparency of the glass, is lost, even should not a defect in the burning have done injustice to the talent of the painter. But if, after all, the artist be bent upon giving to his performance all the harmony of an oil-painting, he must sacrifice the transparency and the liveliness of the colours, which constitute the most beautiful feature of this kind of painting: besides, the presence of the lead-work and the iron bars, which unite the various portions of a painted window, and which it is in vain to attempt to conceal entirely in the shadows of a picture, must ever prove the stumbling-block on which the claim of the artist to imitate oil-painting is sure to founder.

There is a fact which observation itself has demonstrated to an inexperienced artist, and which must lead us to deliberate upon the method of proceeding in practising the art of painting on glass. It is this, viz. that in the colouring of a very elaborate cartoon the half-tints, which have been diversified in gradations of colours delicately and harmoniously blended together, always run together into one colour, producing the same effect in every part as soon as they are viewed at a distance. It is not our intention to account for this remarkable phenomenon, but we content ourselves with merely calling the attention of the glass-painter to the fact, in order that he may join with us in drawing the following conclusion from it.

A painted window of very elaborate execution, which is designed to adorn a building dedicated to the worship of God, and consequently must be viewed at a certain distance, not only loses the fineness of the details, but is also obscured by the blending of the half-tints, and therefore becomes heavy, dry, and hard.

The art of painting on glass, for the purposes of decoration,

is founded solely and entirely upon the observation of the above-mentioned fact. This species of painting, in fact, owes its origin to the necessity which the artist is under of conforming his work to the conditions imposed upon him by the distance at which the spectator must view the painting. What would be said of an artist who thought of treating decorative painting exactly as he would miniature-painting? If we insist strongly upon this truth, it is for the purpose of applying it to painting on glass, which is indisputably a decorative kind of painting, and must be cultivated in this conception, except perhaps in the case of small cabinet windows, similar to those which are known under the name of Swiss-painted glass. If these rare exceptions be not taken into account, the painted glass in church-windows is at such a distance from the spectator, that it would be more prejudicial than useless to attempt perfection and elaborateness of detail, as it is practised in the case of oil-painting. A pure and correct style of drawing, united to a simple and vigorous copying, are the qualities which the painter on glass must, before all things, endeavour to attain.

Unfortunately the assumption of superiority which has impelled mankind in all ages to outdo their predecessors has also misled those who, in modern times, have attempted to revive the art of painting on glass. It is seldom that we avail ourselves of the experience of the former, and we attribute to their impotency that which is in reality the result of mature consideration, which, however, we are utterly incapable of appreciating. Thus, too, it has been taken for granted that the last painters of the sixteenth and seventeenth centuries were not in a condition to make further advances in their art. Their performances were criticized at the same time that they were compared with the contemporaneous productions of oil-painting. The recognition of this principle would, in our opinion, have been more modest as well as more reasonable, viz. that the glass-painters of former times preserved their art free from all imitation; that a long experience taught them to be content with borrowing spirited ideas from oil-painting, and not to aim at producing the same effects by means differing so widely from one another, so that in the end they made painting on glass an isolated art, unlike any other in its effects as well as in its means, and one which is subject to peculiar conditions. But, on the other hand, it has been said that the ancients did not understand the art of painting on glass, and under this impression an attempt was made to execute what *they* had

never been able to perform. This kind of emulation is undoubtedly noble and honourable; but it is to be regretted that such praiseworthy exertions have been misdirected, for, instead of continuing the progress begun by the ancients, when it was so easy to do so, artists consume their emulation in impotent attempts, until a personal experience induces them to resume the labours of the ancients at the point where the latter have left off. We must, however, do justice to him who rescued from oblivion an art that had been so long neglected. For this our thanks are due to the learned superintendent of the royal porcelain manufactory at Sevres, Herr Brongniart, who contributed much to its revival.

We believe we have now satisfactorily defined what we understand by the art of painting on glass. In our opinion there is still a future for this art, if its votaries do but follow the paths marked out for them. With respect to the kind of composition best adapted to it, we shall content ourselves with merely remarking that the good taste of the artist alone must preside over his conceptions. As, however, some have given their opinion in favour of the Gothic style exclusively, others in favour of the style at the period of the revival of the art, according to the several directions which their studies have taken, we cannot forbear expressing our opinion upon this subject. We have no thought of enlisting followers for either party, but without the smallest intention of drawing a comparison in this controversy, we may be permitted merely to hint that the artist should not allow himself to be taken up with these discussions, and that in the conditions of his art alone he has to seek for the spirit that must direct the suggestions of his imagination. He should avail himself of all the resources afforded him by the nature of the things on which he has to exercise his talents. Ought he, for example, to forego the powerful effects which a skilful arrangement of colours enables him to produce? Should he disdain to derive advantage from the lively colouring of the glass because it is the most goodly dowry of the Gothic style of the art? We think not; but we are far from advising him, on the other hand, to sacrifice to such endeavours all the resources of painting which the revival style is capable of affording him, provided that he uses all these means with moderation, and, we repeat it, keeps within the conditions of his art. We submit this opinion to the intelligent artist who does not allow his ardent spirit to be carried away by his ideas; but we have no hope of convincing those who, in the waudering

of their fancy, as well as in the right path, have become the slaves of their imagination.

A very natural question presents itself to the mind, with regard to the erronous belief which universally prevails, that the secrets of the art which were known to the ancients are lost. Are we capable, if not of surpassing, at least of resuming and continuing, the labours of the ancients? When we compare the glass of the old church-windows, of any period whatever, with the glass of our manufactories, we cannot for a moment doubt that our system of manufacturing it produces far more perfect results, not only as far as regards its transparency, whiteness, and clearness, and generally with respect to all those qualities which are peculiar to glass. Besides, it is allowed that the methods of working have been considerably improved. And if, on the other hand, we compare fragments of old painted glass with that which we manufacture at the present day, it will appear in the most convincing manner, that our painted glass is not in the slightest degree inferior in point of colour to that of the ancients. There was a time when the manufacture of coloured glass was discontinued, because, in consequence of the decline of the art of painting on glass, this article was of no further use; but none of the secrets of the colouring were lost. Persons who were little aware of these circumstances, and mistook the effect for the cause, maintained that the reason why the art yielded nothing more was, that the painters on glass no longer understood how to produce the ruby of the ancients. But this assertion was very soon shown to be false; for as soon as the determination to restore painted windows manifested itself, the glass-house of Choisy in France, among others, proved by the most successful results, that the art of manufacturing coloured glass was in no way lost, but was only asleep. In fact, we possess a multitude of receipts of the ancients, according to which coloured glass was produced in former times. Moreover, in pigments we are much richer than the ancients; our pigments, too, are much better, more adhesively enamelled, in consequence of the improvements which have been introduced into the system of burning in the colours in modern times.

From what has been premised, we may conclude that our artists are in no respect in want of the material elements; on the contrary, they are far better aided by resources and means which await their disposal than the ancients were; and if their works attain no remarkable superiority, the reason for it must

be sought for in the fact, that the best means and modes of execution in the arts are unfruitful when they are not employed with sufficient taste and spirit.

Glass-painting has, in our time, risen into life again, surrounded by the fairest hopes; and what we know of the artists who are already practising it, leaves us not the slightest reason to doubt that it will soon be cultivated with a success worthy of the present age. We would gladly contribute, in some degree to draw it forth from the state of oblivion, in which it has been for a long time buried. For this purpose we shall now communicate a number of practical observations which lie in the sphere of glass-painting. We believe that we cannot contribute more effectually to the diffusion of the art, than by clearly laying down the methods employed in its practice. We shall advert to those both of the ancients and of the moderns, and compare them with one another, in order to show the improvements that have taken place, in our time. At the present day, when artists as well as amateurs are most zealously engaged in glass-painting, we flatter ourselves that this information will not be uninteresting to many. Little has yet been written about it, and the majority of the publications that have appeared on the subject treat more of the history than of the practice of the art.

The art of painting on glass by no means consists in the mere application of the colouring materials to the surface of the glass, by methods similar to those employed in oil-painting. The colours used are of a peculiar kind, and possess the power of vitrifying at a high temperature, and of fixing themselves unchangeably upon the glass: consequently the glass, after the paint has been applied, must be exposed to a certain heat in a furnace adapted to this purpose. Appropriate means must also be employed in the application of vitrifiable colours.

A painting on glass—as, for example, a church-window,—always consists of a great number of pieces of coloured glass, whose various hues illuminate an ornamental pattern or an historical subject. These pieces of glass are either symmetrical or irregular, so as to agree with the sentiment exhibited in the composition itself. After they have been arranged in their proper places, they are encased in lead, and united so as to form one complete piece. These pieces are united by an iron frame-work, called the *arming*.

After the brief explanation we have just given of the conditions to which glass-painting is subject, we have to determine

its connection with other arts. In the first place, it is evident that the science of the chemist must be united to the talent of the painter, and that the glazier himself must lend his assistance. We have therefore divided this little work into several sections, in which the various branches of the art will be successively treated of. We have circumstantially discussed the following particulars :

1. The quality of the pigments, their composition, their preparation, and lastly, all the chemical operations which are necessary previous to the painting ;—2. The means used in laying on the colours ; the various methods employed for this purpose, and everything which has reference to the proper art of glass-painting ;—3. The manner in which the vitrifiable colours are burnt in ;—and 4. That part of the glazier's art that is concerned in the putting together painted windows in churches. Finally, we have given an account of the various mixtures, in which the glass is coloured *en masse*.

Glass-painting, as it is practised at the present day, has scarcely anything in common with that of the ancients, as far as regards the colours. When this art, which had been entirely neglected for a whole century, was rescued from oblivion, the improvements in the manufacture of glass had so materially changed the quality of this substance, that the ancient methods employed in the painting were no longer applicable. Towards the middle of the eighteenth century, glass was still composed almost exclusively of flint and potash or soda. This simple silicate was deficient in fusibility, and preserved an extraordinary tenacity even at the highest temperature ; it was difficult to purify, occasioned an enormous expense in fuel, and was not capable of being worked well. In the year 1760, Bosc d'Antic tried a mixture of lime in the form of carbonate of lime, which Kunkel had before proposed. A striking improvement in glass was thus obtained. When combined with silica and with soda or potash, it forms a bisilicate, which is much more fusible than the simple silicates. The proportions of these substances were, however, for a long time badly determined, and it was not till lately that the makers were enabled to impart that fusibility to glass which renders it so easy to work and so cheap to manufacture.

It is obvious that the pigments of the ancients, which were prepared for a hard kind of glass, could not have fusibility enough for the glass which is now manufactured. Other ingredients had to be sought for. But if the ancient methods of painting were no longer in accordance with the quality of

the glass, still less were we acquainted with them. Moreover, the knowledge of enamel colours for metals, as well as for various kinds of earthenware, afforded easily applicable principles, according to which a series of properly fusible colours could be composed. The vast conquests of chemistry within the last fifty years, promised besides, to this manufacture, a very certain success. Modern glass-painting is thus almost entirely of late origin: and, with the exception of the process of burning in, has experienced modifications in every particular in a very remarkable manner. If we believe the testimony of the authors—far back as the period at which Leveil wrote, the glass-painters at that time burnt in their colours in iron boxes, in which the glass was arranged in layers with calcined and pulverized lime strewed between the strata of glass. But towards the year 1758, an English artist made known a new method of burning in, which he employed himself, and which, with some trifling modifications, has remained in use since that time. We shall describe this method more particularly in its proper place. The superiority of this new method of burning in the colour over the ancient method, and especially over that of Leveil, is incontestable. According to the method of the latter, the melted pigments were placed in contact with powdered lime: a portion of this powder adhered to the colours, and injured the transparency. If this was not always the case, the reason was, that the pigments, on account of their slight fusibility, merely adhered to the surface of the glass, and then again its transparency was impaired. The painted windows of the Leveil family furnish a proof of this, and in particular that in the chapel at Versailles, the blues of which are so obscured that they appear black; and among others, Pierre Leveil himself, in his work, admits the fact.

What we have said about the process of burning in, as far back as the time of Leveil, is founded upon the testimony of the writers who have left us some very interesting notices of the state of glass-painting at that period. To these, among others, belong Kunckel, Haudiequer de Blancmont, Leveil, &c. We have not, however, received their opinions upon this matter without due reflection. For how could it be supposed, that in the sixteenth century, when both glass-painting and enamel-painting were so generally honoured and cultivated, it should never have occurred to any of the artists, who were frequently skilled in both arts, to subject the process of burning in to those conditions which are indispensable in enamelling,—namely, a contrivance for heating the plates of glass, isolated and

entirely removed from contact with any other body which can adhere to the colours when in a state of fusion, soil their surface, and deprive them of their transparency? This fact may easily be explained with regard to the former centuries, in which the Gothic style only was cultivated in glass-painting. Because, as this kind of painting is limited to a mere outline upon a ground of glass, coloured *en masse*, little depended upon the smoothness and brilliancy of the colours which were applied in the painting; on the contrary, a complete opacity was indispensable. But in the age of a Peaugrier or a Jean Cousin, when the use of pigments for painting almost entirely superseded that of coloured glass, it is hardly to be supposed that the glass-painters were unacquainted with a method of burning in, similar to that which is now employed. And this is the less credible, inasmuch as the works of this period prove that pigments could be prepared of great clearness, free from all impurity, and just as good as the enamel-painters could produce. It may well be supposed that the traditions of the Leveil family have not informed us what the process was before their time. The progenitor of that family lived somewhere about the end of the seventeenth century. Glass-painting, which was gradually declining, was at that time only cultivated by a few artists. The Pinaigniers, and those of their school, had carried all the secrets of their art with them into the grave; and this was the case at that time with all who practised an art which was enveloped in mystery. Even the very writers who furnished the public with information upon the arts, always reserved that which was most useful for themselves. Cassius did so, according to his own confession, and Leveil made it a subject of complaint against Kunckel and Tammai. Before Guillaume Leveil, but one artist, Jacques de Paroi, had written about glass-painting, and from this common source several authors who followed him, as well as the painters who in the most modern times devoted themselves to glass-painting, seem to have drawn. To the former belong Felibien, Florent le Comte, and Haudicquer de Blancourt; and to the latter the Leveils and the brothers Recollet. This is proved by their receipts, which they have transmitted to us, which are for the most part like one another, and are many of them completely identical.

It may be easily supposed that the Leveil family were unacquainted with the method of their ancestors, who kept it a secret, when it is certain that Pierre Leveil himself, in spite of his profound erudition, was ignorant of what was anterior to

his time, although it had been made known. Fifteen years after the appearance of the English work already mentioned, and actually at the time when he was writing, he still continued to adhere to the manifestly antiquated traditions of his family. However it may be in other respects, we have certainly, in the present state of our knowledge, no reason to envy the ancient glass-painters in regard to their method of operation. Consequently, we have nothing to hope for from pretended discoveries of the secrets of the ancient artists, which were at times so pompously announced, because, as we have before stated, the improvements which took place in the arts in consequence of the progress of science, have placed us in an entirely new situation, which makes the methods of operation that were in vogue at a period far distant from the present time appear utterly useless.

CHAPTER I.

OF THE QUALITY AND COMPOSITION OF THE PIGMENTS.

By the pigments necessary for painting on glass are understood vitrified or vitrifiable substances of various colours, which are applied to the surface of the glass, and fixed by being exposed to a temperature which brings them into a state of fusion.

Several qualities are indispensable to the pigments: 1. fusibility at a given temperature;—2. the power of adhering firmly to the glass and completely uniting with it;—3. a peculiar transparency, or an opacity;—4. a glassy appearance after fusion;—5. a sufficient hardness to resist entirely the friction of solid bodies;—6. insolubility in water;—7. the being unchanged by the action of the air, moisture, and the gases, which are ordinarily diffused through the atmosphere;—lastly, 8. an expansibility equal to that of the pieces of glass that are to be painted with them.

The fusibility of the pigments must always be greater than that of the glass. As the latter becomes soft at a red heat of some intensity, it is necessary that the pigment should be in a state of fusion and become fixed to the glass before it reaches the temperature at which it would be spoilt by bending, from being at the point of fusion.

The pigments are almost always more or less transparent, and only a few must be opaque. In contradistinction to the

other enamel-paintings, which convey to the eye merely reflected rays of light, a painting on glass receives its colour from transmitted rays. We can understand, therefore, that transparency is a quality very frequently necessary to the pigments. It is not always indispensable that this transparency should be perfect and possess the clearness of glass; on the contrary, it is often an advantage when the objects which are behind the window cannot be distinguished. A half-transparency is usually sufficient, provided that it admits of a rich and magnificent colouring; but there are cases in which the painting requires perfectly opaque pigments.

The hardness of the pigments varies according to their composition. They must always possess a degree of hardness sufficient to enable them to resist easily the friction of hard bodies; but since the causes which operate mechanically upon painted windows, to the destruction of the pigments that lie on the surface of the glass, are exceedingly rare, the artist need not always exclude those pigments that are even of moderate hardness.

The resistance of the pigments to the chemical action of bodies must be such that they cannot be affected by any of those agents to the influence of which they are ordinarily exposed, *e. g.* the action of the air, water, sulphuretted hydrogen,* and other gases diffused in the atmosphere; but it matters little whether the pigments are capable of being acted upon by bodies with which they only accidentally come in contact, or not.

The unchangeableness of the pigments is as conditional as that of the glass, and is usually in proportion to their hardness.

Expansibility is one of the principal qualities of which the pigments must possess a precise and accurate amount. In the frequent changes of temperature which the painted plates of glass undergo, during and after the burning, the expansibility of the pigment must be in exact proportion to that of the glass. Were it otherwise, the expansion and contraction taking place irregularly in both bodies, would produce movements in the glass in opposite directions, which must occasion numerous fractures. These are in fact the accidents produced by pigments whose expansibility is ill suited to the glass. Pigments of this kind crack and split, and soon peel off the surface of the glass in the form of scales, while the glass itself, which on

* Gr, hydrosulphuric acid.

account of its thickness possesses firmness and a greater power of resistance, remains uninjured.

The pigments are composed:—1. of colouring materials, which in most cases belong to the class of metallic oxides; 2. of fluxes or vehicles for colour, which are vitreous or vitrifiable compounds, through the medium of which the colouring matter is fixed upon the glass. These fluxes are generally silice, boracic, or borosilicic salts, in which the acids are combined with the bases in certain proportions, and whose state of neutralization varies according to the several indications of which we shall afterwards have occasion to speak.

In order to colour the pigments, the colour which a substance in its uncombined state affords is sometimes employed, sometimes that afforded by its combination with another substance which usually forms a part of the flux. In either case the colouring matter is always mixed with the pigments. This observation admits of a very nice distinction between them, so that we have divided them into two classes.

The first class comprehends those pigments in which the colouring matter is uncombined with the flux, and is in a state of simple mixture, as, *e. g.*, in the case of oil-painting the colour is mixed with the oil. We shall call them *pigments coloured by mixture*.

The second class comprehends those whose colouring matter is in combination with the flux, has become a constituent part of it, and forms with it an entire vitrified mass, possessing all the properties of glass itself. We shall call them *pigments coloured by combination*.

This classification of the pigments has not been invented merely for the purpose of systematical arrangement, but is grounded rather upon practical considerations of the greatest importance.

The composition of the fluxes is not arbitrary. Independently of the peculiar qualities which they must possess in order to be really unchangeable, it is also necessary, since they are the medium through which the union between the vitreous and the colouring matter is effected, that they should be adapted to the nature of the former, to insure their adhesion to it for a long period, and that they should also accord with the qualities of the colouring materials which they have to unite with the glass. The necessity there is for the fluxes being accommodated to all the requirements of the colouring materials, is the principal reason why a much larger quantity of this vehicle must be employed, as we shall show hereafter.

We shall first consider the composition of the fluxes in the several relations they bear to the colouring matter.

In the pigments of the first class it is necessary that the flux be of such a quality that it will preserve the colouring matter in the isolated state upon which the obtaining the requisite colour depends, and that it contain nothing that can effect a change in the properties of the colouring matter. In the fused colours of the second class, on the contrary, it is indispensable that the flux should exhibit a powerful action upon the colouring matter, by which action the combination from which the colour is to be obtained is effected. We shall now make a few observations, from which we shall deduce the principles of the composition of the fluxes, considered in that point of view in which we exhibited them above.

The fixed acids combine with bases in all proportions; but each of these combinations has a certain point of saturation at which, when in a liquid state, it possesses just as little affinity for a greater quantity of base as for a greater quantity of acid. This neutral state takes place in the most easily fusible combination, and the reason is as follows:

If among the combinations of a fixed acid with a base but little or not at all fusible, that be chosen which possesses the greatest fusibility, and an attempt be made to unite with it successively fresh quantities of base, it will be observed that the temperature must be raised in proportion to the increased amount of base brought into combination. Thus, for example, is the case with the silicates of lime, iron, cobalt, copper, &c. If, on the contrary, we wish to add successively to the combination of a fixed infusible acid with a base fresh quantities of acid, it is a well-known fact that the temperature must likewise be raised in proportion to the quantity of acid which has entered into combination. Therefore it may be asserted that in the combinations which consist of a fixed acid and a base, beginning at the most fusible combination, an increase of base or acid requires a proportionate increase of temperature, provided that the substance which is to be added is not very easily fusible, and its combination in consequence independent of the temperature.

The principle which we have just established is certainly subject to modifications, sometimes in favour of the bases, sometimes in favour of the acids, according as they are more or less fusible. In the silicates of lead the same degree of temperature is not necessary for the combination of a quantity of base, as is requisite for the combination of a larger quantity of

acid, because the ready fusibility of the former makes its combination with the silica independent of the temperature. But we have in the borates of iron, cobalt, and copper, an example of the contrary, and here the rule is modified in favour of the bases, because the fusibility of boracic acid renders an increase in the temperature unnecessary. But exceptions like these are not to be found in the combinations we have just been speaking of, if, in the place of the fusible element, an infusible one be substituted in the mixture. This is the case, for instance, when oxide of iron is added to silicate of lead, or silicic acid to borate of lead.

From what has been premised, we infer that when we begin at the neutral state, the temperature which is requisite to unite an oxide with a flux affords a rule for determining the disposition of this flux to become still more saturated. The more it is saturated, the greater difficulty it has in combining with a larger quantity of base, provided that the latter is fusible. The proportions of the base which have to be brought into combination depend upon the temperature; the amount of base is determined according to a given temperature, the above-mentioned cases of easy fusibility excepted. If, therefore, we were to add a fresh quantity of base under the same conditions, it would not enter into chemical combination. This circumstance has now been taken advantage of in the composition of the fluxes of the pigments of the first class.

When the temperature at which the pigments pass into the liquid state is determined, the proper point of saturation for them is at the same time that which is proper for the flux, because we are assured that the colouring matter which has to be combined with it will remain uninjured. If, then, we take the melting point of the pigments at a cherry-red heat, experience teaches us that the triple silicic and the double sub-boracic salts of lead, soda, and potash, which are then completely fused, can be saturated no further. If, therefore, we wish to colour a pigment with an oxide which shall only remain with its flux in the state of mechanical mixture, we must add to the latter the triple silicic and the double sub-boracic salts, of which we have just been speaking.

But if we wish to obtain a colour by means of an oxide which is to enter into chemical combination with the flux, the degree of saturation at which this combination is effected is fixed with as little precision as that of the temperature. If in this case it is judicious to employ a less saturated flux, this may only be done within the limits in which the pigment pre-

serves its indispensable physical properties. As the temperature lends its aid, the combination of the oxide is always obtained. Hence it follows, that however the composition of the fluxes of the pigments of the first class is subject to certain strict conditions, this is not the case with the pigments of the second class. But even in these, as we shall soon see, directions of great importance must be given.

In the composition of fluxes for pigments of the first class we have taken a moderate red heat as the point of saturation, for the following reasons: first, the glass which is painted is capable of bearing only a slight degree of heat, and the standard is its point of fusion, consequently the temperature must not be raised to this limit. Besides, the degree of saturation which we have recommended is at the same time that at which the flux accommodates itself best to the expansibility of the glass, without our being thereby obliged to sacrifice the other desirable qualities of the pigments.

The saturation of the flux, and the temperature which it has to undergo, are, however, not the only things which must be attended to in the composition of the pigments. There are other secondary conditions, which are likewise of importance, partly to prevent the combination of the oxides with the pigments of the first class, partly to favour their combination with those of the second class. The exact degree of heat is not always easily obtained; and if it should happen to be exceeded in the pigments of the first class, the flux immediately regains its power over the colouring oxide. The change in this substance is in proportion to the quantity of flux. Hence we have a reason for prescribing as little flux as possible in pigments of this kind.

An opposite principle directs us to use as much flux as possible in the pigments of the second class. Besides, it is known that a greater saturation of the oxide is still more favourable to its combination. In order that the pigments of the first class may not be exposed to injurious alternations of temperature, the fluxes are not fused together with the oxides before they are required; while, on the other hand, no use is made of the pigments of the second class until a previous fusion has shown a perfect combination of the colouring matter.

We have already observed that the saturation of the triple silicic and double sub-boracic salts has been selected because it fulfils the requirements of the colouring matter and of the glass, without endangering the intrinsic qualities of the pigment. In fact, we are strictly obliged to confine ourselves to these limits

if we wish to avoid the unpleasant results that have been mentioned above.

When a salt of silicic acid and a metallic oxide is combined with a silicic salt, having an alkaline base, by the agency of heat, the one is dissolved in the other. Does this result from an act of combination, or from simple mixture? The learned observations of Dumas upon the fortuitous crystallization of glass have proved that the different kinds of glass are composed of certain definite silicates, and we have reason to believe that they are in a state of combination with one another. But even independently of the quality of these silicates, their various states of saturation produce numerous modifications in the properties of these compositions. The most important fact, however, which has been noticed, is the following: Mr. Faraday has observed, that if only a slight addition be made to the quantity of oxide of lead which the common flint glass contains, this glass, which before was quite proof against moisture, then acquires the property of a hygrometer in a remarkable degree, and in damp air soon loses its transparency. Several others have ascertained the truth of this fact from their own experiments. Flint glass is a silicic compound, of which the acids contain eight of oxygen to one of base. Whenever glass in general contains a greater quantity of base, it is much more easily affected by water. This may be said of window-glass, looking-glass &c., especially when they have been polished. All these combinations yield an alkaline silicate, which is soluble in boiling water, and an insoluble siliceous earth is precipitated. This takes place at the various degrees of saturation which lie between the octosilicate and the bisilicate. But it is a very remarkable fact, and one which has been especially observed with regard to those glasses which contain lead, that if flint glass, containing a soluble alkali, be reduced to a bisilicate in such a way as to be combined with a greater quantity of lead, this flint glass when pulverized gives up almost all its alkaline silicate in cold water, and that, too, almost immediately.

Hence it is that the combination of a silicic salt of lead with an alkaline silicate, which is very easily decomposed in mass, in proportion as we descend from the octosilicate, possesses no stability at all when we reach the bisilicate; for then the latter has become soluble in cold water, and is immediately dissolved in it. It is, however, probable that this is not the case with all bisilicic compounds; for basic silicates are combined with one another in those kinds of glass which contain lead, whilst

in bottle-glass, for example, silicates of any kind are combined with basic silicates, and combinations like these have more stability. But our business here is only with the silicates which contain lead; for the pigments that are usually employed almost always contain lead. The reason of this is, that the silicic salts of lead are extremely useful in modifying the expansibility of the pigments. By increasing or diminishing the quantity of oxide of lead, we almost always succeed in imparting a degree of expansibility to the pigments equal to that of the glass. The same result cannot be obtained from an alkaline silicate. This shows us the reason why potash is avoided in the composition of the pigments. The necessary fusibility and expansibility require that the fluxes should be brought into that state of saturation in which they have very little stability, and are very liable to decomposition. At a high temperature the potash is decomposed, and evaporates; when cold, the pigments are easily affected by moisture. This disagreeable circumstance is avoided by substituting for the potash borate of soda: the latter is much more fusible than the silicate of potash, and consequently enables us to obtain a proper fusibility without lowering too much the degree of saturation. And so less colouring, less liability to change, and greater hardness, are simultaneously obtained.

The whole matter may be shortly summed up thus:

1. In the pigments coloured by mixture, those silicates only may be used whose acids contain at most three times as much oxygen as the bases.

2. In the pigments coloured by combination a greater quantity of oxygen in the acids can only be of advantage when all other conditions have been complied with.

3. No pigment containing lead is to be prepared which contains the silicate of an alkali in a state of saturation beyond that of the trisilicate; that is to say, which contains a smaller portion of acid, or a greater quantity of base.

4. In every case, the indispensable conditions of fusibility, hardness, and expansibility must be satisfied.

In the composition of fluxes, silicic and boracic salts of various metals are usually combined, because the salts formed by these combinations possess greater fusibility, and because among the simple silicates and borates, which might, perhaps, be sufficiently fusible, they would not have the requisite whiteness if they were employed alone. For instance, the silicic and boracic salts, which contain a great quantity of base, would possess sufficient fusibility, but they have a yellow

colour, which is more distinct in proportion as they are saturated. It is therefore necessary to combine them with a certain quantity of alkaline silicates or borates, in order to render this colour less conspicuous.

It would be better if the silicic or boracic salts which are used in the pigments were all insoluble, like those of lime, aluminium, lead, &c. But the necessity for obtaining a great degree of fissibility requires the use of alkaline silicates and borates, which, within certain limits, obtain a sufficient stability from their combination.

From the principles which have been laid down above, it might seem that two kinds of fluxes are sufficient for the two classes of pigments. Thus would certainly be the case if nothing more than the proper colour were attended to in the preparation of the pigments. But these pigments, which are made on purpose to be laid on the glass, must possess the same expansibility as the latter. Now the physical properties of the pigments are modified in a remarkable degree by the various substances employed in colouring, collectively and separately, in different ways. Consequently, it is only by changing the nature of the flux that we are capable of imparting the requisite expansibility to the pigments. Hence, also, arises the necessity for the existence of a great variety among the fluxes. When we come to treat of the pigments particularly, we shall also specify the fluxes proper for each. We shall, however, mention a few here, which may be adduced as an illustration of the rules we have laid down.

FLUXES FOR PIGMENTS OF THE FIRST CLASS.

	No. 1.	No. 2.	No. 3.
Silica	1 pt.	3 pts.	2 pts.
Oxide of lead	3 "	8 "	6 "
Calcined borax	0 "	1 "	1 "

Haudicquer de Blancourt, who has described the preparation of the flux No. 1, in his *Art de la Verrierie*, calls it *rocaille*, and it was formerly used as a glaze for common pottery-ware. This flux, however, whose state of saturation is admirably adapted to the preparation of pigments of the first class, cannot be advantageously employed in every case. It frequently happens that a colouring oxide, when mixed with it, contributes to its decomposition, since it favours the separation of its elements. The pigment then undergoes a change on exposure to the air, the surface loses its brightness, and crumbles to powder. We are, however, unable to specify the nature of

the action of the colouring substances. Perhaps, it is only mechanical, and proceeds from the great distribution of parts, and from the porosity itself, which a powder in the state of simple mixture imparts to the pigment; perhaps, too, the oxide of lead has less affinity for the silica than the new substance which tries to supplant the first.

The rocaille flux is, after all, only employed with advantage in the pigments of the first class when they have previously to be melted. The more intimate mixture of the flux with the colouring matter then imparts a greater density to the pigment, which defends it again at the action of the air. We prefer this explanation. When the pigment does not require to be melted first, it is advisable to substitute No. 2 or No. 3 for No. 1; for they are only a modification of the latter, and possess greater stability.

FLUXES FOR PIGMENTS OF THE SECOND CLASS.

	No. 1.	No. 2.	No. 3.	No. 4.
Silica	3 pts.	1 pt.	3 pts.	3 pts.
Minium	8 "	8 "	5 "	6 "
Borax	3 "	2 "	3 "	2 "
Saltpetre	0 "	0 "	1 "	0 "

Every pigment might be prepared according to the above directions, if nothing but the good quality of these vitreous compounds were had in view. But those pigments chiefly that are to be produced by combination are so changed in regard to their expansibility by certain oxides, *e. g.* those of copper and manganese, that, in order to destroy the effect of the latter, it is necessary to reduce the fluxes to a state of saturation, which cannot be done by the use of alkaline silicates, for they must be employed in such small quantities that they may be enveloped, as it were, by the other silicates, and thus protected from the action of the water.

In this case the fluxes are very much saturated and less fitted to dissolve the oxides. But even then, methods may be employed to facilitate their combinations, which we shall describe when we come to speak of the pigments in particular.

OF THE PREPARATION OF THE PIGMENTS IN GENERAL.

The preparation of the pigments, which embraces a number of particulars with regard to each, may, however, be reduced to two general methods of operation, according as they are coloured by mixture or by combination.

In the first case, as we have already said, a flux in which the base preponderates is chosen; and with this object in view,

care is taken, at the same time, that the colouring oxide shall remain as short a time as possible in contact with the liquefied flux: for this purpose they are only mixed together by means of the runner upon the mill-stone,* and the mixture is not heated until it is ready to be laid upon the glass, and exactly as much flux is used as is necessary to give body, smoothness, and brilliancy, after the burning in, to the pigment.

In the second case—1. A pigment must be selected in which the acid predominate as much as possible;—2. It is also necessary to heat them together in a strong heat, in order to facilitate the reaction;—3. The flux must likewise be present in as large a quantity as possible without injuring the richness of the colouring;—4. The oxide must be perfectly free from combination, which might impede its union with the flux.

These are the most important varieties of the pigments, with regard to their composition and preparation. We subjoin some further considerations concerning the pigments collectively, that is to say, concerning the means of modifying their properties according to circumstances.

With respect to transparency, the pigments coloured by simple mixture are remarkably dissimilar to those which are coloured by chemical combination. It will be readily understood, that an opaque colouring matter diffused through a glass vessel diminishes the transparency of the latter, so that the enamel which is produced by it will be less perceptible to light than another which has been coloured by a substance dissolved in the flux. It is also just as evident, that in the former case the opaque colouring matter diminishes the transparency of the flux in proportion to the quantity in which it is added to it. Thus the transparency of the pigments is increased according as the quantity of colouring matter is diminished. But this can only be done at the cost of the colouring, and in such circumstances, where intensity of colour is not required, it will be better even to impair its stability; for the more flux there is, the greater the action known to take place upon the colouring metallic oxides. With regard to the pigments of the second class, their transparency can only be diminished by the mixture of substances which impart opacity to them.

The hardness of the pigments under circumstances in other respects the same, increases in proportion to the quantity of

* Described under the head 'Mill for grinding the pigments.'

the silica. This is just the case with regard to their resistance to the action of chemical agents. Consequently the opposite effect is produced as soon as the base is made to predominate.

We now come to their *expansibility*. It is of great importance to make this property of the pigments accord with that of the glass: it may, however, be very easily modified in the case of the former. With regard to this, we believe we have observed, that in the borate, silicate, and borosilicate of lead, the base usually produces the opposite effect to that of the acid; but we are unable to state whether the one diminishes or the other increases the expansibility. It is enough for us to know, that if a pigment becomes full of cracks, the proper degree of expansibility may easily be imparted to it either by increasing or diminishing the quantity of oxide of lead. We would recommend here the former method as the proper one in almost all cases.

FUSION OF THE FLUXES.

After the requisite quantities of the various substances that are to be used for a flux have been levigated and accurately weighed, nothing more remains than to fuse them. The powder is first well rubbed and mixed in a mortar. After careful mixture, it is put into a covered crucible, which is placed in the furnace; a gentle heat is first applied, which is gradually increased, until the whole is brought into an undisturbed state of fusion, and all bubbles have ceased to form. The crucible is then taken out of the furnace, and the contents are poured into a vessel of cold water: they are then collected and dried upon paper. The action of the cold water splits the mass into small fragments, which can afterwards be more easily levigated. Without this precaution, the flux would concrete into a vitreous mass, difficult to pulverize. This is exactly the mode of operation when we have to combine a flux with a colouring metallic oxide for a pigment of the second class, as is the case with all vitrifications of fluxes or pigments.

If we would have our colours bright and pure, it is of essential importance that the pigments should be prepared from none but the purest substances. It is consequently necessary that we should be well acquainted with the properties of the substances to be employed. We therefore think it advisable to make a few preliminary remarks concerning some of them.

and to give a full account of them afterwards in their proper places.

Silica.—Silica is produced from flints, and white ones, or those of a beautiful black colour, are selected for this purpose. The yellow flints are less pure, and contain a great quantity of iron. For this purpose they are heated red-hot, and then thrown into cold water to quench them. If the action of the cold water fails in cracking them in such a manner as to allow of their being easily crushed by the fingers into a coarse sand, the operation is repeated; they are then reduced to powder, and rubbed through a silk sieve. This powder must then be washed, and the supernatant water poured off, as long as a fine powder continues to float on the surface, which gives the silica a yellow colour. This powder appears to consist of impurities, which originate partly from the furnace, partly from the cast-iron mortar which is employed in levigating the flint: they seem to be united with very fine silica, which could better be spared than retained in company with these foreign bodies. The particles of iron, being very fine, are carried off by the water in which the powder is washed, and separated before the process of heating the silica (of which we shall presently speak), in which those particles of iron would otherwise be further oxidized, and might not be so easily affected by acids.

After the silica has been washed in the manner above described, it is strongly heated and thrown a second time into cold water. The little grains of which it is composed undergo a fresh division, which facilitates the action of the acids with which they come in contact, and also the fusion of the metals. They are now treated with hydrochloric acid, washed and dried. Silica might also be obtained in the same way from white granular quartz; but even the purest granular quartz contains a greater quantity of iron than flint does, on which account the preference is usually given to the latter.

Borax.—The borax which is used in the preparation of the pigments is *fused borax*, which must not be confounded with *calcined borax*. The latter contains still a greater quantity of water. It is indispensably necessary to make use of the fused and perfectly vitrified borax, not only to enable us to calculate the quantities exactly, but also to avoid the swelling which would take place if borax in any other form were employed.

We shall hereafter enlarge more minutely upon the manner in which this operation is performed. When the borax is in a state of fusion, and appears perfectly clear, it is poured upon

a smooth stone: it then presents the appearance of a beautiful white and entirely colourless glass. It must now be kept in a bottle well corked.

Minium.—The *orange-coloured minium*, as it is called, is most usually employed: it is the purest, and can be used without requiring a particular preparation. We shall only observe, however, that the minium must part with 2.23 per cent. of oxygen, in order that it may be reduced to the state of protoxide.

Of the other bodies which are used for fluxes we shall have occasion to speak elsewhere. Now that we have finished treating of the pigments in particular, we intend to subjoin a few general reflections, which we recommend to the consideration of the reader.

GENERAL REFLECTIONS CONCERNING THE COLOURING MATERIALS.

The chief colouring substances of the pigments are metallic oxides. Sometimes they are simply mixed with the whole body of the glass; at other times they are combined with the silica; and probably form double salts with the silicates of the fluxes. The analogy which prevails between the pigments and the other kinds of glass supports this hypothesis. It is known that in these compositions such alkaline silicates as are soluble in water when uncombined become almost insoluble as soon as they are combined with other silicates, *e. g.* with silicate of lime, silicate of lead, silicate of aluminum, &c.

Now the combination of these bodies is the sole means by which their properties can be modified.

In the pigments coloured by mixture, the colouring oxides are not always used separately; sometimes several are employed, after they have been previously combined with one another. But the conditions to which they are mutually subject are always independent of the flux.

The oxides which are combined in a pigment of this description do not give it the colour which the mixture of their respective colours would produce, but they give it peculiar shades of colour, which are determined by their state of combination.

Several oxides are frequently employed also in the pigments of the second class, but are not combined with one another, and the colour which is obtained is only the result of the mixture of the colours which each oxide produces of itself.

The combination of the oxides with one another is a valuable auxiliary in the preparation of the pigments. Sometimes these combinations impart to the oxides a greater power of resisting the action of the flux; at other times, on the contrary, they facilitate their solution in the latter. It is evident, at once that the former are used for the pigments of the first class; the latter, on the other hand, for those of the second class. In the former case, we should combine oxide of iron, for instance, with oxide of zinc; because the former, by virtue of this combination, which possesses great stability, would prove much more powerful in resisting the action of the flux, and thus the real colour of the oxide could be given to the pigment.

In the second case, on the contrary, we should combine oxide of cobalt with oxide of lead, so that their less stable combination may bring the former of these bodies into a state of fine division favourable to the action of the flux. This direction may be complied with in a very simple manner, if, instead of preparing the flux beforehand in order to combine it with the colouring matter by a second fusion, the colouring oxide be heated when mixed with the ingredients of the flux; for the oxide of lead, which forms one of these ingredients, will dissolve the colouring oxide, and by that means dispose it to combine more easily with the silica. We have therefore no hesitation in prescribing this method universally for the preparation of the pigments of the second class. We know no reason of sufficient importance to oblige us to use fluxes previously vitrified, as is the case with the pigments coloured by mixture.

The combination of two oxides forms a real salt, in which the one appears in the character of the base, and the other in that of the acid. We shall now give a list of these bodies, in which those that act as base and those that act as acid are classed according to the energy they exhibit:

ACID OXIDES.

Antimonic acid.
Antimonious acid.
Stannic acid.

Oxide of aluminum.

Oxide of zinc.

BASIC OXIDES.

Protoxide of iron.
Protoxide of manganese.
Protoxide of lead.
Oxide of silver.
Oxide of bismuth.
Protoxide of cobalt.
Oxide of copper.

INDIFFERENT OXIDES.

Protoxide of tin.
Oxide of antimony.
Oxide of chromium.
Sesquioxide of manganese.
Oxide of iron.

We shall now give a few examples of the above-mentioned compositions, as they are frequently employed :

Antimonite of lead	Yellow.
----- cobalt	Dark green.
----- copper	Pistachio green.
Perantimonite of iron	Bees'-wax yellow.
----- zinc	Yellow.
Zincate of iron	Yellow ochre colour.

It is evident that a great number of combinations similar to those we have mentioned might be formed. A variety of mixed gradations of colour are obtained from these compounds, which in painting are called *broken tints*, and which are of great service to the artist. Among these compounds are :

Ferrate of manganese,	Manganate of cobalt,
----- chrome,	----- copper,
----- cobalt,	----- chrome,
----- copper,	Cuprate of silver, &c.

We shall treat of the preparation of these colouring substances hereafter.

CHAPTER II.

OF THE PIGMENTS IN PARTICULAR.

Red for the flesh-tints.—This pigment is coloured with oxide of iron, as it is obtained by calcining the green vitriol of commerce; but it must first be purified, principally in order to rid it of the sulphate of copper, which it almost always contains, and which, when the pigment is used, turns the red black.

Purification of the vitriol.—Dissolve the vitriol in twice its weight of cold water, and throw into the solution iron turnings, iron filings, or iron cuttings of any kind. The sulphate of copper will be decomposed, and the copper precipitated in the metallic state, in the form of a reddish powder. The solution should be stirred from time to time, and after the precipitation is completely at an end, the liquor poured off and filtered. To know whether all the copper has been precipitated, dip into the solution a bright blade of iron, and see whether it is covered with a surface of red copper.

The filtered solution of sulphate of iron must be put into an

iron or leaden vessel, which is placed in a common oven, in order that it may become so concentrated by boiling as to have lost $\frac{2}{3}$ ths of the water which has been taken into solution. Its specific gravity will then be 40° of Beaumé's areometer, and the solution will begin to grow turbid; it is then left to crystallize in a wooden vessel covered with wax; twelve hours afterwards the mother-liquor is poured off, and the crystals are collected, strained, and dried.

Drying of the salt.—In order to dry the salt, and to perform the subsequent operation, two pounds of salt at the most should be treated at a time, for the sake of greater facility in manipulation.

Two pounds of the purified crystals are accordingly put into an iron vessel, which is placed in a furnace, and a moderate fire is applied, in order to melt them in their water of crystallization. When this has taken place the liquid mass begins to boil, and soon assumes the consistency of thin paste and the colour of clay softened by moisture. After it has become concentrated the temperature is lowered, that the melted mass may not boil over. In proportion as the water evaporates and the contents of the vessel are drying they are continually stirred, and during this process the bottom of the vessel especially must be scraped with an iron ladle having a long handle, until the salt is at length converted into a more or less coarse powder. It is now allowed to cool, after which it is pounded in an iron mortar, and finally rubbed through a silk sieve. In this state it is fit for the preparation of the red pigment.

Preparation of the red pigment.—For this operation a very thick cast-iron vessel is required, and it is not a matter of indifference whether merely a common iron vessel of moderate thickness be employed for this purpose or not; for there would be a danger of its being perforated with holes and destroyed before the conclusion of the operation: cast iron is more durable than wrought iron when applied to this use.

An earthen cylindrical furnace must likewise be employed, with a bottom of the same substance, and open at the top. A hole is bored at the bottom, to receive the muzzle of a small smith's bellows. The dimensions of this furnace must be six inches in diameter, and the same in height. In default of such a furnace, a common one might be used, but the temperature can be regulated much better in the one we have just described; for as soon as the operator ceases to blow, the fuel, receiving no air from any quarter, begins to go out. The vessel must be of the same width as the furnace.

These proportions for the furnace and the iron vessel must be adapted to the quantity of the salt that can be used at once, in order to perform the operation with due precaution.

The sulphate of iron, prepared according to the above directions, is heated until it assumes a dark red colour. Meanwhile it is continually stirred with an iron scraping instrument until the operation is finished, in order that fresh surfaces may be continually exposed and the whole may be uniformly heated. The powder at first becomes yellow, then brown, and at last assumes a greenish brown appearance, which after cooling changes to red. An acid and pungent gas is now disengaged. The operation is continued until the powder is reduced to about two-thirds of its volume. It is now taken from the fire and allowed to cool.

After a little practice, we may know by the colour of the substance when the operation must be brought to a conclusion. Should the operator, however, want experience, let him take portions of the substance at different periods of the operation, and he will thus be sure of obtaining the requisite tint. In every case the operation must be concluded before the gas has ceased to be given off; for if it were prolonged to this point, it would be all to no purpose, and the result could only then be used as a dark brown or iron violet colour.

The red which has been obtained is put into a vessel, and boiling water poured upon it to dissolve the sulphate of iron that has not yet been decomposed. It is frequently stirred, allowed to subside, and the supernatant water is poured off. The red pigment is then cleansed from a few impurities remaining in it by being stirred in a vessel of fresh water, which is quickly poured off as soon as these impurities have subsided. If this operation be repeated as often as is necessary, the impurities will be completely removed. They are generally of a greenish grey colour. The powder of oxide of iron is now washed in a filter with cold water until the latter exudes from the filter perfectly tasteless. The result, when dried, is now ready to be mixed with the flux.

Theory.—What takes place in this operation? In the first place a portion of the acid of the salt is decomposed into sulphurous acid which is given off, and oxygen, which converts the rest of the salt into persulphate of iron, which is mixed with the oxide of iron that has been liberated. This sulphate is now decomposed again; sulphuric acid is disengaged, and oxide of iron, mixed with undecomposed persulphate, remains.

It is well known that the red oxide of iron changes its colour

in proportion as the temperature to which it is exposed is increased. At first it possesses a yellowish red colour, which afterwards passes into a darker red, and finally into violet. If, therefore, it is required to produce a delicate red for the flesh-tints by calcining sulphate of iron, the latter must be acted upon by a heat sufficient to decompose it, but still not so great as to deepen the red which has already formed. Hence is evident the importance of always keeping it at a dull red heat, and of stirring it incessantly, so that the parts which lie at the bottom may not be too much heated. With respect to this circumstance we subjoin the following practical remark, viz. that in order to keep the powder at a dull red heat, while it is stirred, the bottom of the vessel must be at a cherry-red heat.

The operation must be concluded before the sulphate is all decomposed (and this is of the greatest importance), so that the red which is formed may be mixed with a certain quantity of this salt. When the latter has been dissolved by the water in which it is washed, the oxide that remains is in a state of finer division, and possesses a lively red colour.

If the operation be continued too long, it seems to be prejudicial to the beauty of the red, even if the temperature be not very high. We may infer from this, that the oxide condenses not only in consequence of the high temperature to which it has been exposed, but also on account of the length of time during which it has been heated. And this is the reason why only a small quantity of the salt should be operated upon at a time.

Red of a beautiful tone from iron may be obtained with much greater certainty by a method which is based upon the theory we have just explained. A mixture of sulphate of iron and sulphate of potash is calcined, as in the foregoing operation, these salts having been previously combined in the state of solution, and then evaporated and dried by heat. The mixture may be heated merely in a crucible, provided that care is taken to increase the temperature slowly up to the dull red heat, and to keep it so until the operation is finished. But this latter method is less certain. In every case the undecomposed sulphate of iron, as well as the sulphate of potash, is separated by repeated washings with hot water.

There is still another method which furnishes a red of great richness of colour, particularly for the flesh-tints. It consists in grinding sienna in a solution of sulphate of potash. drying it by heat in an iron vessel or even in a crucible merely, and calcining it the proper length of time at an incipient red heat,

in order to develop^d the colour of the oxide of iron. The product is then washed with boiling water, to separate the sulphate of potash.

A similar result is obtained by calcining a mixture of equal parts of green vitriol and alum, previously united in solution, and proceeding in other respects according to the method we have just described for obtaining the red from sulphate of iron and sulphate of potash.

The preparation of the red from iron requires much more delicate manipulation than would be supposed. Whatever method be employed, the calcining must be performed with the greatest care, and we would particularly caution the reader against imagining that the details we have given are superfluous. It is difficult to determine which method of preparation deserves the preference, because, on a comparison of the various methods, we cannot always be sure of being subject to the same conditions, and we often lay to the charge of the method that which ought properly to be attributed to the manipulation. If we were to recommend one method more than another, it would be the second, that which we have most frequently employed.

It now remains for us to explain why sulphate of potash is used in the preparation of the red obtained from iron. This salt is unchangeable at a red heat, and at this temperature has no chemical action upon the component parts of the sulphate of iron. Its action here is entirely mechanical. It supports, as it were, the complete decomposition of the sulphate of iron.

But, although it remains undecomposed itself, its presence is by no means a matter of indifference. When the sulphate of iron is dried in contact with the sulphate of potash, it is kept by the latter salt in a state of fine division, analogous to that which it possesses in the state of solution; for every minute particle of iron is surrounded by numerous minute particles of sulphate of potash, so that, when the oxide of iron is separated, it must preserve the extremely fine division of the salt by which the oxide of iron was produced. It thus escapes that condensation and conglomeration which oxide of iron always undergoes when it is heated by itself. The unchangeableness of sulphate of potash at a red heat is the only reason why this salt has been selected for the operation in question. It is likewise employed for the same purpose in similar cases, where, as in the present instance, the object is to obtain oxides free from water in a state of the most minute division. There are various methods of applying it to this purpose.

1. Sulphate of potash is calcined at a red heat, together with the metallic sulphate whose oxide is to be obtained, provided that this sulphate is decomposable. The process is the same as has been described in the case of the red obtained from iron.

2. If the salt is not decomposable, the oxide in question is precipitated with potash; the solution is then evaporated to dryness, and the product is submitted to a red heat in a crucible. The sulphate of potash is next removed by boiling water.

3. If the oxide of another salt, not a sulphate, is to be obtained, we proceed as follows: after the oxide has been precipitated with potash, and the precipitate washed, it is mixed with a saturated solution of sulphate of potash, next evaporated, and the rest of the process is the same as we have described above.

M. de Montani treated certain oxides, probably with the same object, with chloride of sodium in a similar manner, but his efforts were misdirected. He triturated red oxide of iron and chloride of sodium dry in a mortar together, and calcined the mixture in a bright red heat. In this way he calcined oxides, free from water and already condensed by the action of the fire, with the chloride. The oxides could not penetrate so deeply into the latter combination, which was applied in a solid state; as if it had been in the state of a red-hot liquid; and besides, they had undergone a very great change from the heat before it was introduced.

The red pigment is composed of

Red oxide of iron	1 part.
Flux No. 1, or No. 5, of the 1st class	3 parts.

The flux must be pulverized before it is weighed, because a certain quantity is always lost by pulverizing it in an iron mortar. It is then mixed with the oxide of iron, and the mixture levigated; at the same time a sufficient quantity of water is added to obtain a liquid paste, which is afterwards dried on plates.

This pigment must contain as much flux as will give it brilliancy when it is exposed to a cherry-red heat; a larger quantity of flux must, however, be avoided, because the flux would re-act upon the colouring oxide, and contribute to the production of a green silicate of iron which would be prejudicial to the purity of the red. We shall afterwards explain how this pigment is to be prepared for use, and

under what conditions it must be heated after it has been laid on the glass.

If a greater degree of freshness and brilliancy is required in the red pigment which is used for the flesh-tints, a certain quantity of chloride of silver must be added. The yellow tint which this combination produces imparts a greater liveliness to the red colour of the iron. The taste of the artist can alone determine the proportion of the substance to be added. The chloride of silver must previously be fused with the flux. The oxide of iron is added afterwards.

Purple (purple-red) pigment.—The preparation of the purple is a very delicate operation, the success of which is extremely uncertain. The reason of this is, that the method which is employed in the majority of cases for the preparation of a solution of tin furnishes an exceedingly variable compound, although the process is on every occasion the same. The precipitate which by this method is apparently obtained under exactly the same conditions, frequently varies from a more or less lively purple to a violet more or less dark, and even of a blackish colour; and even the purple of the most beautiful tone is not always proof against the drying, and is turned black by the separation of the gold.

The method employed in most cases is as follows: Take aqua regia of 8 parts nitric acid and 1 part sal-ammoniac, diluted with twice its weight of distilled water. Set the apparatus in a cold place, and introduce small pieces of tin one after another in proportion as they are dissolved. The action of the acid must be slow, and without a considerable quantity of heat being evolved. When the liquor has assumed a yellow colour, not very intense, it is fit for use. On the other hand, dissolve pure gold in aqua regia containing 1 part nitric acid to 2 parts hydrochloric acid. The gold has now to be precipitated by means of a solution of tin. For this purpose, a few drops of the solution of gold are poured into a glass, and at least a thousand times their volume of water is added. Into this liquid some of the solution of tin is introduced, a drop at a time, until the water is coloured red. This liquor is kept in a vessel by itself, and the same process is repeated until at length the requisite quantity of purple is obtained. In a few moments the purple collects in red flakes, which sink to the bottom. As soon as all the purple is precipitated the supernatant liquor is poured away. It is then washed several times with distilled water, which is likewise poured away. Next it is filtered, and whilst it is still moist it is triturated with its flux

The success of the operation depends upon the manner in which the salt of tin is prepared. In order that the purple may be of the proper quality, the action of the acid upon the tin must be neither too strong nor too weak; if it is too weak, too much protochloride of tin is obtained, and if it is too strong, nothing but perchloride of tin is produced. It is necessary to know how to keep the acid in exact equilibrium, so as to obtain a mixture of the two salts combined in as nearly as possible the proper proportions. The difficulties which accompany the regulating the effect of the acid in such a way as to obtain every time the same result, although the operation is not performed under the same conditions of temperature, are obvious to every one. Sometimes the protochloride, at other times the perchloride, is in excess: this explains the different appearances which this composition exhibits when used.

If the products of the operation are uncertain, variable in their colour, and disposed to decomposition during the process of drying, there is every reason to believe that the salt of tin is of a bad quality. The difficulty of imparting the requisite properties to this composition induced M. Reboulleau, among others, to seek for a simple and easy method of procuring with certainty a solution of tin adapted to the preparation of the purple. It is composed in a way that Dumas also considers the best, viz. of one atom of protochloride and one atom of perchloride of tin.

The method employed by M. Reboulleau for this purpose is as follows: Protochloride of tin is first prepared by introducing grains of pure tin into a leaden vessel which can be closed by a lid of the same metal. A small quantity of concentrated hydrochloric acid is then poured upon the grains. The apparatus is gently warmed in a sand-bath, and small quantities of acid are gradually introduced until the tin is dissolved. The liquor is evaporated to 10° of Beaumé's areometer, and allowed to crystallize. We have then merely to convert a definite portion of the protochloride of tin into perchloride. The crystallized protochloride is dissolved in a sufficient quantity of water; the solution is divided into two parts, one of which is set apart, while chlorine gas is infused into the other until the protochloride is completely changed into perchloride, which is removed for fear it should precipitate gold. This solution is added to the one which was set apart, and thus a solution of tin is obtained, in which the two chlorides are present in accurately determined proportions. The success which this method insures in the preparation of the purple is so per-

fectly certain, that it may be safely recommended to glass-painters and other artists.

The solution of tin serves only for precipitation from chloride of gold which is prepared by dissolving gold in aqua regia composed of 1 part nitric acid and 4 parts hydrochloric acid, evaporating it until it is dry, in order to drive off the excess of acid, and adding a quantity of distilled water sufficient to dissolve the salt which has been obtained.

The precipitation of the purple is a part of its preparation that requires very delicate manipulation. The manner in which the mixture of the two salts is effected is not a matter of indifference. Two methods may be employed: the solution of gold may be poured into the solution of tin, or *vice versa*; but these two methods do not promise equal success. The following remarks will show why one method is to be preferred to the other.

When the precipitation of the purple is effected by the mixture of the salts of tin and gold, one of these three things will take place: viz., either the salts will be in proper proportions, or the salt of tin will predominate, or the salt of gold will be in excess.

If the salts are in proper proportions, the purple precipitate follows, accompanied by certain indications with which it is necessary to be acquainted. The liquor assumes an intensely red colour, similar to that of wine. The precipitate does not follow immediately, but the purple remains a longer or shorter time, as the case may be, in the solution, and frequently it is several hours before the separation is complete. When the precipitation takes place too quickly, it is always a proof that the purple is of a bad quality and contains an excess of gold.

If the salt of gold is in excess, a precipitate is formed which varies from a pale rose colour to a more or less lively red, and the separation takes place immediately. In this case also the purple is imperfect.

If, on the contrary, the salt of tin predominates, no formation of purple takes place; the liquor assumes a yellowish or rose-coloured appearance, without affording any precipitate.

From what we have just stated, any one would be inclined to think that if the quantities of the two salts are previously determined, it would be sufficient to pour the solution of the one into that of the other, and to stir them together. But this expectation is not easily realized; and it is thought more advisable to obtain a proper mixture by adding successive drops of the solution as long as it shall be found necessary;

nor even then is it immaterial whether the solution of tin be poured into the solution of gold, or the solution of gold into the solution of tin.

Is the solution of tin to be poured into the solution of gold?

As the addition is made by drops, the gold remains in excess in the liquid until the whole of the solution of tin has been introduced. Consequently an imperfect precipitate may be formed if the proper quantity of the solution of tin be not introduced with tolerable rapidity; and this is very frequently the result. If, on the contrary, too much solution of tin be added, no precipitation takes place, and it becomes necessary to reverse the operation, and to add the solution of gold. This method is therefore very uncertain.

Is the solution of the salt of gold to be poured into that of the salt of tin? So long as the salt of tin is in excess no precipitation takes place; but if we continue to add gold the purple soon makes its appearance, and we can always stop at the right time, because we are not obliged to hurry ourselves in the least degree. Only an inexperienced operator runs the risk of introducing too much solution of gold. In such a case, a precipitate of bad quality would be produced, and the experiment would entirely fail.

It is evident that, of these two methods, that according to which the solution of gold is poured into the solution of tin has the best prospect of success, and is the least liable to accidents. It may be asserted that it is the only one which affords invariable results: it admits, too, of the treatment of any quantity we please, while the other method is only applicable when the solution has to be treated with a few *decagrammes** at a time.

But whatever method be pursued, the solution of tin must at all events be diluted with a thousand times its weight of water, in order that the precipitate may be so much the more finely divided and more gelatinous. After the precipitation of the purple powder has subsided, it is put into a filter and washed with distilled water: it is advisable then to dissolve it in ammonia, and keep it in a well-stopped bottle: the capability of being dissolved in ammonia is the test of its good quality;—if this property is wanting, we may be certain that it is of no use, for it will not possess durability.

In order to unite the purple with its flux, the latter is pul-

* The *decagramme* is equivalent to 154.12 English grains avoirdupois (the *gramme* being 15.412 grains), according to the new metrical system of weights and measures.

verized, moistened with the ammoniacal solution of the purple powder, and the mixture is effected by levigating them together upon a plate of glass. The relative quantities of the purple and the flux depend upon the richness of the colour which is intended to be given to the pigment. One-tenth of the purple in a dry state gives an intense colour. If we know the composition of the purple, the quantity of gold that is used, the quantity of ammonia in which the purple has been dissolved, it is an easy problem to determine the proportions of this solution, which must be added to the flux, in order to have used the equivalent of one-tenth of dry purple.

The purple colour which is produced in fused pigments by the above-mentioned composition proceeds from metallic gold in a state of exceedingly fine division. The same colour is likewise obtained from pure chloride of gold, sulphuret of gold, and fulminating gold, in similar circumstances, and these combinations play the same part as the purple powder. When the latter is mixed with its flux, and strongly heated, the tin is separated from the gold, but the latter, reduced to the metallic state, remains in a state of the most minute division, because the flux, being melted, is present in a liquid form. But as soon as the gold can collect together in particles of a larger size, there is a transition from red to violet and blue. This phenomenon is produced by several circumstances, which arise from the following causes :

The flux for the purple must contain not much lead, but, on the contrary, a great quantity of acid, and must at the same time possess great fusibility. Stannic acid has in fact a great affinity for oxide of lead. When it is combined with gold in the form of the purple powder, and is brought into contact with a flux containing a large amount of base, and at the same time lead, it leaves the gold in order to combine with the lead before the pigment is completely melted. This premature separation of the tin from the gold facilitates the agglomeration of the particles of the latter, which then assume the violet or blue colour we have been speaking of.

A large proportion of acid gives more stability to the silicate and borate of lead, so that it is more capable of resisting the action of the stannic acid.

The colour of the purple is, on the other hand, destroyed when the flux with which it is mixed wants fusibility. The temperature necessary to fuse the mixture produces at the same time the decomposition of the purple before it can be brought into its incipient state of division. So also a purple

pigment mixed with its flux, if too strongly heated, would undergo the same change from a contrary action, because the too great fusibility of the flux is favourable to the condensation of the gold. Consequently it is necessary that the purple, at the moment when it is being decomposed, should be held in solution in a dense mass of liquid glass, in which every one of its particles may, as it were, remain isolated, in the same way as an oleaginous body is suspended in a slimy fluid.

The flux which seems best adapted to the purple is the following:

Calcined borax	7 parts.
Silica	3 "
Minnium	1 part.

This flux possesses sufficient fusibility, and at the same time great stability.

Another still more fusible flux :*

Calcined borax	7 parts.
Silica	3 "
Minnium	1 part.

These substances are fused together.

Another still more fusible flux :

Calcined borax	7 parts.
Silica	1 part.
Minnium	1 "

These substances are likewise fused together.

For the purpose of obtaining a still more fusible flux, it is not unusual to increase the quantity of borax very considerably, without employing the other substances in larger quantities. Thus, for example, the following flux is used :

Calcined borax	12 parts.
Sand	1 part.
Minnium	1 "

A flux like this is, indeed, far more fusible than the foregoing, and more conveniently used for glass-painting, because only a moderate heat is required for it ; but such a composition is liable to imperfections, and is not only more easily affected by moisture, but is also in the habit of coming off in scales. The purple colours generally possess these imperfections. It is owing to the great quantity of acid which they contain that their expansibility does not accord with that of

* There is evidently some mistake in the original, this and the foregoing flux being perfectly identical.

certain kinds of glass. When this kind of painting is looked at with a magnifying glass, after the burning in, several cracks and fissures may be observed; and after a certain time, especially when the painting has been exposed to moisture and a variable temperature, it scales off, so that at last the glass becomes perfectly bare. It is of importance to examine in every case whether the pigments agree well with the glass in regard to expansibility, and it is frequently necessary either to vary the composition of the flux or to choose another kind of glass.

A carmine tint is given to the purple by adding to it a small quantity of chloride of silver, previously fused with ten times its weight of the flux which is used for the purple.

As the purple from gold is prepared in different manufactories in a great variety of ways, and the preparation is attended with various results, we shall conclude by stating several methods, for which we are indebted to men whose reputation is great in the scientific world.

According to Bastemire Daucenart, the purple is prepared in the following manner: Nitric acid and gold are taken in the proportion of 8 parts, by weight, of the former to 1 of the latter. In order, however, that the operation may be performed with greater certainty, it is better, in case the acid should be more concentrated at one time than at another, and in order that similar results may be always obtained, to introduce gold into a retort until the acid is completely saturated. Especial care must be taken that the solution of gold is in a perfectly neutral state.

The nitro-muriatic acid,* for the solution of gold, is composed of

Nitric acid	1 part.
Muriatic acid	1 part.

The former acid is poured into a retort, which is placed in a heated sand-bath, the muriatic acid is then introduced, and the liquid is at the same time stirred; a few minutes after, the gold is thrown into it, a small piece at a time. Gold riband should be preferred, which may be bought at the goldbeater's, or else the gold, if it is at all thick, should be beaten very thin. When the acid is observed to be incapable of dissolving any more gold, the retort is taken out of the sand-bath and placed upon a layer of rushes of a concave form, to receive the globular part of the retort. The liquid is left for some hours

* This is erroneously called 'Salpetersäure,' nitric acid, in the original.

by itself, after which it assumes a beautiful dark yellow appearance.

The solution of tin is likewise made with nitro-muriatic acid, but instead of 4 parts of nitric acid 6 are used, and the following compound is obtained:

Nitric acid	6 parts.
Muriatic acid	1 part.
Distilled water	4 parts.

The solution of the tin requires infinitely greater care than that of the gold; it must take place without any effervescence, and very slowly. Tin leaf, such as is used for covering mirrors, is selected for this operation. The solution takes place without heat, and only a very small quantity at a time is introduced into the acid which has been diluted with water; *e.g.* pieces of tin leaf eighteen *millimetres** square, one after another, for the space of twelve hours, until the acid is completely saturated. When both the solutions have been prepared in this way, the one is precipitated with the other; and this is the moment when it is the most difficult to obtain a beautiful purple. Many persons have been quite discouraged, and have given up even attempting to prepare this colour, because they have undertaken the operation too carelessly, when, in fact, it requires great nicety, or because they have not clearly understood the theory of the phenomena which take place in the mutual decomposition of the two soluble salts. Care must first be taken that both the solutions are very considerably diluted with water, for without this precaution gold is precipitated by the tin in a metallic state, which causes such a cohesion of the minute particles of the metal, that the desired results cannot be obtained in the precipitate. To avoid this disagreeable occurrence, which renders the whole operation fruitless, a large glass vessel, three parts full of distilled or at all events very pure water, must be taken, and into this a certain number of drops of the solution of gold must be poured. The number of drops must be in proportion to the size of the vessel. Suppose the vessel is capable of containing one *litre*† of water, as much as eighteen drops of the solution of gold may be dropped into it. This done, the liquid is stirred with a piece of the tube of a barometer, and it must then be of a pale yellow colour, but very clear; eight, ten, or twelve drops of the solution of tin are then dropped

* The *metre* is 39·37079 English inches; the *millimetre*, being the 1000th part of the *metre*, is therefore equivalent to 0·03937079 inches.

† The *litre*, or cubic decimetre, is 2200967 of an imperial-gallon.

into the vessel, and care is taken to stir the mixture well, just while the solution is being dropped. As soon as the liquid is observed to have assumed a colour, like that of red wine, no more solution of tin is added, (we should suppose that this would take place at the sixth drop,) because if the process be continued after the beautiful red colour has appeared, only a purple is obtained, which approaches too near to violet.

There must be a large vessel of porcelain, or well-glazed Delf ware, ready to receive all the red liquid which is transferred from the glass vessel into which the solution of tin was dropped. Accordingly, when the liquid in the latter vessel is well saturated with the purple colour, it is introduced into the large vessel of Delf ware, and a fresh quantity of water is poured into the glass vessel, and then eighteen drops of the solution of gold. Whilst the solution of tin is being dropped, the liquid is stirred with a glass rod: the drops of the solution of tin must never amount to more than two-thirds of those of the solution of gold, especially if the purple is to be of a beautiful rose colour.

When as much gold and tin as is considered necessary has been precipitated, all the water which has been coloured red is poured together, and then left undisturbed. In the course of twenty-four hours a reddish brown precipitate settles at the bottom of the Delf ware vessel. To hasten this subsiding, one or two pinches of kitchen salt may be thrown into the red liquor. Some writers have also recommended the addition of a certain quantity of fresh urine; but some solution of phosphorus may be more advantageously substituted for the latter. In other respects, it is far better that the subsiding at the bottom of the vessel should take place slowly and of itself, and in that case the supernatant liquor must be perfectly clear. This is poured off, and the remainder edulcorated several times with plenty of water: the precipitate is collected upon a piece of white paper, and dried in the shade. In the course of a few days it is easily removed from the paper, whereupon it is put away in a wide-mouthed bottle with a greased stopper, and kept from the light.

The formation of the purple proceeds:—1. from the elective affinity of gold and tin; 2. from the high state of oxidation of the tin; and 3. from the circumstance that the solutions are diluted with a great quantity of water, to weaken the affinity of the acid for the oxides as bases; for so long as the metals (gold and tin) are intimately combined with the acids in which they are dissolved, there is no chance of obtaining a purple of a beautiful colour.

Moreover, all the precipitates which are obtained by means of gold and tin differ from one another in a variety of circumstances. The quantity of water poured in to the first vessel, namely, in that into which the solution of tin is dropped to mix with the solution of gold; the number of drops of the solution of tin in proportion to the number of those of the solution of gold; the purity of the water in which the precipitation is effected: all these circumstances might produce a great variety of tints. However, in general the purple is the more disposed to assume a violet colour when the precipitate contains a greater quantity of tin in proportion to the gold; on the other hand, the purple is more beautiful or more rose-coloured, the more solution of gold the precipitate contains. It is therefore quite at the option of the experimenter to prepare a more or less beautiful purple, if he only act upon this intimation with proper care. Proust and Oberkampf* have analyzed several red and violet-purple precipitates; they found, in a beautiful rose-purple—20.58 oxide of tin, and 56.42 gold; and in a violet-purple precipitate, 60.18 oxide of tin, and 39.82 gold.

According to Berzelius, the purple contained—28.35 oxide of gold,—65.00 oxide of tin,—7.65 water.

According to Buisson, the purple precipitate contains—28.50 gold,—65.00 oxide of tin,—5.20 chlorine.

Cassola, Professor of Chemistry at Naples, gives the following receipt for the preparation of the purple: By bromochlorate of gold is prepared in the usual way: at the same time, tin filings are digested in vinegar for two or three days, and the solution is filtered. The solution of gold is then diluted with four or five times its weight of water, and the solution of protacetate of tin is generally poured into it until the red precipitate has formed; it is then washed and bottled up.

Cassola asserts that he obtained the same results by using a solution of protonitrate of tin, procured from tin filings, dissolved in concentrated nitric acid which had been diluted with fifteen parts of water. According to what he says, this solution of protonitrate of tin must not be used until it has been for two days in contact with the tin. Both solutions—that of the tin and that of the gold—must be mixed cold, in which case a purple precipitate, without a tinge of black, is immediately produced. Cassola, however, prefers the process with

* *Annales de Chimie*, t. lxxx. et lxxxvii.—(Note of the Author.)

acetate of tin. It is also employed protosulphate of tin, diluted largely with water, for the precipitation from the solution of gold, and obtained the same favourable results. The same phenomenon, however, with regard to the colour of the precipitate, takes place in precipitating with sulphate of tin, if it is used in excess, as if muriate of tin is employed in too great a quantity.

A beautiful purple may also be obtained by the following method: One part thin gold leaf is dissolved in aqua regia, the solution is poured into a glass, and diluted with 15 parts rain water; a solution of 1½ part clean tin filings in muriatic acid, which has been allowed to cool, is added, and at the same time the mixture is continually stirred. After it has remained a quarter of an hour undisturbed, one-half part clean urine is poured into it, and the whole is well stirred. About two hours afterwards the liquor is poured away from the purple, which has now subsided, and the latter is completely edulcorated.

According to Stegers, a very beautiful purple is prepared in the following manner: Fine gold is dissolved in aqua regia. If the gold has been alloyed with silver, the solution is poured away from the precipitated chloride of silver; the latter is washed with distilled water and added to the solution, which, without being filtered, is evaporated with a moderate heat until a thick incrustation of crystals is formed, and only a little of the red solution bubbles up from under the incrustated surface when the vessel is inclined on its side. The whole is now left to cool, whereby it gradually solidifies throughout, and is dissolved without delay in ten times its weight of water; to avoid the attraction of moisture, the solution is filtered, and a small quantity of metallic gold is left behind. In order to wash out the filter, a portion is reserved out of the water, which has been accurately weighed, and this is afterwards added to the solution. The crystallized salt of tin of commerce is quite good enough for the purpose; if it is moist it should be dried between printing-paper. One part of this salt is dissolved in four parts of distilled water; the solution is filtered and used immediately, because in time it becomes turbid, owing to its attracting oxygen from the air, and submuriate of tin is deposited in the form of a white powder. Next, 1 part of gum-arabic is dissolved in 3 parts of hot distilled water, and the solution is filtered through gray blotting-paper, because printing-paper, on account of its greater closeness, impedes the passage of the glutinous fluid. When the three liquids have

been prepared in the foregoing manner, 20 grains of the solution of gum are mixed with 3 ounces of distilled water, and, after careful stirring, 14 grains of the solution of tin are introduced. The vessel in which the latter was weighed out is rinsed with a little water, the whole is then mixed with 23 grains of the solution of gold, and the vessel which contained it is likewise rinsed, not with water, but with the mixture itself. The colour which arises from the above-mentioned proportions of these ingredients is a fiery reddish brown; it is only in the fire, when this preparation is used for glass-painting, that it develops a purple unequalled in beauty. The colour may be slightly affected by the action of the acid which has been disengaged by the formation of the purple in the liquid; but this is obviated by diluting the solution with twice its weight of water, dissolving 10 grains of bicarbonate of potash in it, and mixing with it, according to the above direction, some of the solution of tin containing gum.

To separate the purple, whose precipitation is at present retarded by the gum, alcohol is added to the mixture until it grows very turbid; for this purpose about twice its weight of 75 per cent. spirit is required, that is to say, if bicarbonate of potash has been used, otherwise three times is necessary. In the course of an hour, if the solution has been occasionally stirred during this time, the purple is precipitated in reddish brown flakes, and the supernatant liquor remains clear, with only a slight tinge of colour. This is decanted, and the precipitate is then washed with some more spirits of wine; it is strained through a filter of printing-paper, gradually deprived of its moisture by being squeezed with the latter through blotting-paper, removed to a rubbing saucer, and then ground with weak 50 per cent. spirits of wine to a thin paste, which is boiled for three minutes in a vessel proper for the purpose, and then poured into a cylindrical glass. As soon as it has subsided in this vessel, the liquor is poured away, and is replaced by twice as much water. This operation is repeated, by which means the gum is removed, all except a slight residue, which can do no harm. Should the purple subside very slowly from the last liquor, and form a dense, almost transparent, red stratum over the sediment (a fact which proves a disposition to be dissolved), the water must be poured away, and a small portion of strong alcohol must again be added to the remainder, in order that the purple may coagulate rather more densely, and the last addition of liquid may be filtered. In either case, the precipitate from which the liquor has been

strained is pressed, as before, with the *filtr*, between blotting-paper, and, while moist, is scraped off with a blunt knife, and dried in a porcelain saucer, whereby it diminishes considerably in bulk, and becomes of a perfectly dingy colour.

According to Buisson, the purple is prepared with the greatest certainty in the following manner: 1 *gramme* of the purest tin is dissolved in a sufficient quantity of muriatic acid. The solution must be neutral. Further, 2 *grammes* of tin are mixed with aqua regia, composed of 3 parts of nitric acid and 1 part of muriatic acid, so that the solution contains no protochloride of tin. Lastly, 7 *grammes* of fine gold are dissolved in a mixture of 1 part of nitric acid and 6 parts of muriatic acid, and this solution must likewise be neutral. The latter is diluted with $5\frac{1}{2}$ *litres* of water, the solution of perchloride of tin is added to it, and that of the protochloride is introduced a drop at a time, until the precipitate that is being formed possesses the requisite colour. This precipitate is edulcorated as quickly as possible.

It is of importance to know that the perchloride and the protochloride must not be produced separately, but both the chlorides at the same time, to enable us to obtain the purple from chloride of gold; and that it is further requisite that the three chlorides should be prepared for use perfectly free from acid.

Herr G. Creuzburg,* a practical chemist, particularly recommends, in the preparation of the purple, the use of a solution of tin chemically pure; he therefore advises that the broken tin ore should be first treated with nitric acid, which dissolves all other foreign metals, and converts the tin into an oxide. After the blue solution which contains the foreign metals, and among others copper, has been poured away from the oxide, which is in the form of a white powder, and the latter has been washed, dissolved in muriatic acid, and inspissated, chloride of tin, chemically pure and free from acid, is obtained. It now only remains to observe, that perchloride of tin, digested with metallic tin, gives protochloride of tin. When the two solutions of tin have been prepared in this manner, the remainder of the operation is performed according to Buisson's method. After a few slight preliminary experiments have shown about the maximum of perchloride of tin that the solution of gold will bear, in order to give the purple with the protochloride, the requisite quantity of perchloride is

* Journal für praktische Chemie, herausgegeben vom Prof. Erdmann and Prof. Schweigger-Seidel. Bd. ix. Heft. 6.—(Note of the Author.)

poured all at once into the very dilute solution of gold, which is not thereby rendered turbid, and a slow precipitation is produced by the introduction of the protochloride, very much diluted, until the purple tint appears.

It was now a still more difficult task to find a suitable flux, and other ingredients, in order to obtain a beautiful enamel colour. At last it was discovered that antimony and white enamel were the substances which, when mixed with the flux, were capable of lightening the tint of fine purple, so that the rose colour was particularly beautiful. The addition of metallic silver and chloride of silver, by which the purple colour used formerly to be brought out more strongly, was not applicable to this purple, and gave a useless colour, mingled with a horny-looking yellow, even on the addition of a very minute quantity of these substances.

Porcelain, of different kinds of glazing, gave various tints with one and the same purple. Herr Creuzburg observes, that antimony not only brings out the purple tint more finely than any thing else, but also gives considerably more body to the colour, so that it bears more flux, and consequently a given quantity goes further.

Persons who were experienced in the preparation of a beautiful purple, and with whom he was personally acquainted, assured him that they never used the precipitate of Cassius in the preparation of their finest purple, unless they had obtained it accidentally. According to their assertion, the precipitate, which is of a grey colour approaching to violet, should give the most beautiful purple; the dirtier the colour of the precipitate, the more brilliant the purple which it gives when fused. This dirty precipitate should contain more gold, and urine should be employed in its preparation.

Frick, the privy-counsellor of the mines, gives the following process for the preparation of the purple: Tin is dissolved in very dilute aqua regia, without the application of heat, until the liquid begins to assume slightly the appearance of opal; the tin is then taken out and weighed, the liquid is diluted with a very great quantity of water, and some dilute solution of gold and dilute sulphuric acid, in certain given weights, are simultaneously poured into it whilst the mixture is being stirred. The quantity of the solution of gold to be poured into the solution of tin must be such that the weight of the gold will be to that of the tin as 36 to 10.

We are indebted to Professor Fuchs, of Munich, for a remarkably simple method of preparing the purple. A solution

of pernuriate of iron is added to a solution of protochloride of tin until the former loses its colour and assumes a greenish tinge. The mixture is then diluted with water, and some of it is poured into the solution of gold which has been properly diluted. The most beautiful purple is immediately produced, while the protoxide of iron remains in the solution without having any injurious effect. The precipitate becomes lighter-coloured in drying, and appears as a dirty brown powder.

Herr C. F. Wapau considers the method of Professor Fuchs the best, judging from his own experience, but recommends the following process in the preparation of the purple powder: Let a solution of perchloride of iron be diluted with three parts of water, to which let a solution of protochloride of tin, prepared from one part of protochloride of tin dissolved in six parts of distilled water by means of a few drops of muriatic acid, be added, until the mixture has assumed a greenish colour. Let this mixture be further diluted with six parts of distilled water, and kept ready for use. If both the solutions were to be diluted at once with the whole quantity of water, the transition of the brown into the greenish colour would not be so clearly perceived. In the mean time, let pure muriatic acid be poured upon so much gold as is required for the operation: let the whole be heated to boiling, and pure nitric acid be introduced, in small quantities at a time, until all the gold is dissolved: an excess of acid, especially nitric acid, should be avoided. To this solution let a portion of distilled water (360 times that of the gold to be used) be added, and some of the solution of iron and tin be poured into the mixture, whilst it is being stirred, as long as precipitation takes place. The precipitate will be of a beautiful purple, when dry will appear browner, but will dissolve in ammonia and fused pigments with an intense purple colour.

Dr. Bolley, however, could not always obtain exactly the same preparation according to the above method; he therefore attempted to procure a solution of the sesquioxide of tin in another way. The combination of chloride of tin and chloride of ammonium (*pink salt*, as it is called, a salt consisting of an equal number of atoms of chloride of tin and chloride of ammonium) seemed very well adapted to this purpose. This salt is anhydrous, and not affected by the air, so that when exposed to dry it undergoes no changes which would be likely to induce an unscientific chemist to adopt wrong methods of proceeding. It contains an accurately balanced quantity of chloride of tin not liable to change, and this very circumstance renders it

adapted to the preparation of the oxidized matter which lies half-way between the protoxide and the peroxide.

Dr. Bolley does not recommend the production of this sesquichloride of tin by the use of a prescribed weight of perchloride of tin dissolved in water containing muriatic acid, because any directions for doing this would be uncertain on account of the various quantities of water which the salt of tin contains, and partly on account of the increased oxidation of the latter: experience alone teaches us that perchloride of tin boiled with tin can be converted into the protochloride, and consequently, if the right quantity of tin be used, into the sesquichloride. According to Dr. Bolley's experiment, perchloride of tin combined with sal-ammoniac is the same in this respect as perchloride by itself. The pink salt contains 70.8 per cent. perchloride, of which 32.3 per cent. is tin: if this amount of tin be increased by one third, the quantity of chlorine remaining the same, sesquichloride will be produced from the perchloride. Consequently 100 pink salt requires 10.7 metallic tin. Dr. Bolley subjected pink salt and tin in the proportion we have specified, together with water, to the action of heat until the tin was dissolved: he then used the solution for the precipitation of the purple.

We now proceed to give a more detailed account of the experiment: 1.24 grammes of gold were dissolved in nitromuriatic acid, an excess of acid being carefully avoided, and the solution was diluted with 480 grammes of water, the proportion specified by Capann. To 10 grammes of dry pink salt he added 1.07 of tin filings; 180 grammes of water were weighed out, and of these about 10 grammes were immediately brought in contact with the tin and pink salt, and heat was applied until the tin was dissolved. The solution was now mixed with the remaining 140 grammes of water, and some of it was gradually introduced into the slightly warmed solution of gold until all precipitation ceased: the precipitate soon subsided, was taken out of the filter, washed and dried at the temperature of 100° C.: it weighed 4.92 grammes, and had become dark brown. The strained liquor was yet only of a pale red colour. The precipitate dissolved when digested in strong ammonia. The gold which it contained (calculating from the quantity of gold consumed) amounted to 21.4 per cent., a result which is most in accordance with Fuchs' analysis of the purple: he found in it 19 per cent. of gold. In either case, every one who is engaged in the preparation of the purple for the purpose of applying it to the arts, will find in what we

have stated an infallible means of obtaining, the most efficacious proportions of the peroxide and the protoxide of iron that have yet been discovered.

Of the Blue.—The blue pigment receives its colour from oxide of cobalt, and belongs to the class of fused pigments which are coloured by chemical combination. The oxide of cobalt combined with silica and boracic acid acts as base. This pigment is also one of those which require to be fused before they are employed. As the peroxide is the most easily prepared of all the oxides of cobalt, it is usually mixed with the flux, for we know that it passes into protoxide at a high temperature. This change takes place much more rapidly and more effectually when assisted by the action of a fixed acid. The presence of the flux satisfies the latter condition. The peroxide of cobalt is reduced in contact with silica and boracic acid, and readily unites with them in the state of protoxide. The ease with which the reduction and combination take place is naturally in proportion to the abundance of silica or boracic acid in the flux. But if, on the contrary, the flux contains too great a quantity of base, the cobalt, upon which the action of the acids is now less powerful, is reduced with difficulty to the state of protoxide, and requires an intense heat to effect a perfect combination; and even then the colour is seldom pure, and a blackish blue tint is usually obtained. A other circumstance, viz. impurity, contributes to impede the solution of the cobalt in the flux. There are even anterior combinations of cobalt with certain oxides, which, whenever they happen, render it extremely insusceptible of the action of the flux. In this case it very frequently assumes a greenish tint. It is therefore evident that everything which contributes to resist the conversion of the peroxide into the protoxide opposes the combination of cobalt with the acids of the flux. The whole resistance lies in this; for if the protoxide is for a moment produced, it is rapidly absorbed again, as will appear from the following remarks.

Certain necessary conditions of expansion frequently require that the vitrification of the cobalt, contrary to the directions we have given, should be effected in very saturated fluxes. In such a case its combination is assisted in a remarkable manner by the following process. If a certain quantity of oxide of antimony be added to the peroxide of cobalt at the moment of its mixture with the flux, by virtue of its great affinity for the oxygen, it rapidly and completely effects the reduction of the peroxide of cobalt. The antimonious acid which is thereupon

produced does not injure the purity of the colour in the slightest degree, and does not perceptibly impair the transparency, provided that too much oxide of antimony is not used. It is extremely probable that the protoxide of tin produces the same effect.

A mixture of oxide of zinc and peroxide of cobalt produces the same effect in another way. The remarkable endeavour of the oxide of zinc to enter into various combinations with the protoxide of cobalt affects the peroxide in the same way as the silica itself.

Phosphoric and arsenic acid likewise favour the solution of protoxide of cobalt in the fused pigment, whether they are added in an isolated state or in combination with the cobalt itself, that is to say, in the state of phosphates and arseniates. In the former case, they act by increasing the quantity of the acids; in the latter, because they contain cobalt in the state of protoxide. It is then only necessary to mix them with the flux.

We have said that the peroxide of cobalt is generally employed in order to obtain silicate of cobalt, which colours the fused pigment blue. The principal reason why this is chosen is, that if protoxide were used, it would be converted into peroxide before the combination is effected, because it burns at a red heat. The carbonate would furnish the same result. But a combination of oxide of cobalt with oxide of zinc, which resists the action of heat better, may be employed with advantage. This combination is obtained by dissolving one part of sulphate of cobalt and two parts of sulphate of zinc in a sufficient quantity of water. Into this liquid a solution of carbonate of potash is poured until no more precipitate is produced. This precipitate is placed in the filter, washed, and dried, and is then the composition which was required.

Not only does the oxide of cobalt produce the richest colour of all the oxides, but also a very small quantity only is necessary to impart a very deep colour to the fused pigment. The blue pigment is composed as follows: Peroxide of cobalt 1 part, or zincate of cobalt 3 parts, flux from 6 to 9 parts.

The flux which is used for the blue pigment is one of the three which we have specified among the fluxes for pigments of the second class. The flux and the oxide are levigated together, the mixture is put into a crucible, which is kept at a red heat until the contents are perfectly fused and all ebullition has ceased; the pigment is then poured into cold water, dried, and levigated.

The oxide of cobalt is employed in various proportions according to the strength or weakness of the colouring. The taste of the artist is easily satisfied in this respect.

As far as regards the blue pigments of the ancients, they are the best of all their compositions. The receipts of Felibien and Haudicquer de Blancourt, which we possess, afford a very excellent coloured glass. The blue pigments that Leveil and the brothers Recollet used to employ seem to have been drawn from the same source, although the imitation is not very correct. This pigment was composed in the following manner:

Minium	1 part.
Oxide of cobalt	1 "
Silica	1 parts.
Nitrate of potash	3 "

It is a quadrisilicate, and reminds us of M. Guinant's composition of kint glass. For 2 atoms of oxide of lead, 2 atoms of protoxide of cobalt are substituted here.

This enamel, like the majority of the ancient ones, is not capable of being used as a pigment, on account of its slight fusibility. However well it might have been adapted to the window-glass of the ancients, it is certainly unfit for the glass of the present day, which is much more fusible.

The saturating point of this pigment was applied by the ancients to other colours, particularly to green, on account of which we have dwelt longer upon it than we should otherwise have done.

Of the Yellow.—The fused pigments may be coloured yellow by a great number of substances.

A lively and brilliant colour is obtained by means of metallic silver. The oxide of uranium by itself, when dissolved in a flux, furnishes also a beautiful yellow; but, in most cases, those oxides which are used as colouring materials are combined with one another by twos, and often in greater numbers. Thus, *e.g.* we combine protoxide of lead with antimonic acid; protoxide of lead with oxide of iron; oxide of zinc with oxide of iron; oxide of iron with antimonic acid. Other compounds likewise furnish useful yellow pigments. Among these are chloride of silver, chromate of lead, &c.

Each of these colouring substances produces the colour which belongs to it.

Silver gives a yellow varying from siskin yellow to purple.

The oxides of lead and antimony also furnish a siskin yellow, but it is opaque.

The oxides of zinc and iron give an ochre-coloured yellow. Chromate of lead, too, yields a very lively yellow tint, &c.

Among all these colouring substances, the chloride of silver, zincate of iron, and antimoniate of lead, are considered the best. The three tints which are produced by these colouring materials satisfy all the requirements of glass-painting.

Yellow from silver.—This colour is obtained without the intervention of a flux. The process consists in covering those parts of the glass that are to be stained with a paste composed of chloride of silver and calcined yellow ochre, both levigated together with water. After the glass has been heated to a red heat in the muffle, the layer of ochre which adheres to the surface is removed by means of a spatula, and the glass is found to be stained. The yellow obtained in this way varies from siskin yellow to purplish yellow. It is not always, however, at the option of the artist to obtain any of these tints whatsoever, for some kinds of glass are stained by this process only bright light yellow, while others are capable of receiving a deep orange colour. The orange colour is frequently only to be obtained by repeating the process once or twice.

That kind of glass which, when plastered over with clay, is most disposed to lose its glaze, and which partly or entirely gives up the potash which it contains, seems to receive the best colour.

Dumas is of opinion that the white kinds of glass, those which contain a great quantity of aluminum, are the best for staining with silver, and they are the very kinds which, according to this chemist, can be the most easily deprived of their glaze. In the act of parting with their glaze, which is effected by the assistance of a paste or cement, a formation of certain silicates which crystallize, and a separation of a part of the bases, take place. Those of them which are volatile, *e.g.* the alkalis, are disengaged, and the fixed oxides, *e.g.* those of iron and manganese, pass into the state of sesquioxide.

This is the case with regard to the separation of a portion of soda or potash, upon which the colouring of the glass by means of silver depends. When the glass is covered with the paste of clay with which chloride of silver is mixed, and exposed to a red heat, the chloride is volatilized, its vapour saturates the glass, and as soon as it comes in contact with the potash which has been liberated, the silver is reduced to the metallic state; chloride of soda or chloride of potash is produced and volatilizes, while the metallic silver is fixed upon the surface, and often even penetrates a considerable depth into the body of

the glass. If the quantity of reduced silver is small, the colour is siskin yellow. If it is more considerable, the yellow becomes deeper, and passes over into a more or less intense red.

The latter colour may be obtained in less time, and with greater certainty, by using glass with which a certain quantity of chloride of silver has been mixed at the moment of its manufacture. For this purpose the glass must be well refined, and contain no excess of uncombined alkali by which the chloride of silver would be reduced too soon. The colouring is then effected in the manner we have already described.

That it is the reduced metallic silver which produces the colour in the glass has been demonstrated by very decisive experiments.

If we take glass with which $\frac{1}{200}$ th of its weight of chloride of silver has been mixed, heat it red-hot, and in this state cause a stream of hydrogen gas to pass over its surface, the glass immediately receives an intensely red colour, which result is likewise obtained by covering the glass with pure clay. In the former case, the action of the hydrogen gas upon the chloride of silver is manifestly the principle upon which the colouring of the glass depends. Now the action of this gas consists in reducing the silver to the metallic state; for if the quantity of chloride of silver be increased, the surface, when acted upon by the hydrogen gas, is covered with a stratum of silver possessing a metallic lustre.

The same colour is also produced, as we have stated, by the surface being in contact with a layer of clay, and we believe that the nature of the process by which it is produced is exactly the same. It does not appear, however, as if the clay effected this by an immediate action, that is to say, by the reduction of the chloride of silver. We attribute this action to one of the phenomena which accompany the depriving the glass of its glaze, namely, to the volatilization of the potash.

Even up to the present day, the staining the glass yellow has been attributed to the oxide of silver; but experience incontrovertibly proves that this effect is produced by metallic silver. In this there is a striking analogy between the manner of colouring of the latter and that of gold. The yellow or red colour proceeds from the silver in a state of extremely fine division, and the purple from gold in the same condition.

When the silver is in such a state of division as to be capable of colouring the glass, it only continues so under certain conditions. Accordingly, as soon as the yellow is produced, care must be taken not to let the glass pass into the

state of fusion, for, in the disturbance produced by the motion of the liquid mass the particles of silver assemble in larger groups, from whence arises a new colour in place of the former. The silver in this state of less minute division assumes a very intense blue colour. Hence we arrive at this practical conclusion, viz. that silver is only capable of colouring glass at that moment of its formation at which it has been brought to the proper density, and that for the colouring of fused pigments, it can only be used within certain limitations of flexibility at a heat which the glass shall be able to bear.

We have one or two more words to say upon the preparation of the paste for the yellow. Ferruginous clay is used, commonly known by the name of *yellow ochre*. This clay must be calcined, otherwise the paste which is laid on the glass would be full of cracks, in consequence of the diminution in bulk which clay undergoes when exposed to a strong heat. Those parts of the glass which correspond to these cracks would then receive no colour. Consequently, the yellow ochre must be raised to at least as high a temperature as the glass in the muffle.

The relative quantities of chloride of silver and burnt ochre are as follows :

Chloride of silver	1 part.
Ochre	from 6 to 12 parts.

A greater proportion of chloride of silver would cause the paste to adhere too strongly to the glass. The chloride of silver and the clay are carefully rubbed upon a glass plate with a sufficient quantity of water to form a paste, which is applied in a thick layer to the surface of the glass by means of a paint-brush.

This yellow is frequently employed to give brilliancy and liveliness to the red obtained from iron. In this case it is applied to the side opposite to the painting.

Chloride of silver, by itself, is also capable of staining the fused pigments yellow; but then it imparts to them a colour of its own, if it mixes with them without being decomposed. Here metallic silver is not the cause of the colour. The chloride of silver must be fused with its flux in the proportions of from 1 to 2 parts of the former to 10 of the latter. When united to one of the fluxes for pigments of the first class, it is used as a mixture to the flesh-red to give it brilliancy. With the purple it produces a carmine tint, and only a very small quantity requires to be mixed with it.

The yellow pigment which chloride of silver furnishes can also be employed in an isolated state.

Orange colour from silver.—This orange colour is only a shade of the yellow from silver which we have been speaking of, and is likewise prepared in the same way, except that for chloride sulphuret of silver in the same proportions is substituted. Similar phenomena may be observed during the process, and metallic silver is always the element of the colour. Orange yellow is obtained with much greater certainty from sulphuret of silver, while on the other hand chloride of silver answers much better for a light yellow, although it is not always in our power to produce any given colour.

Red from silver.—A red colour is also infallibly obtained by using sulphuret of silver. In this case the preparation which was employed for the orange yellow is slightly modified by adding a few drops of sulphuric acid at the moment when it is being used. If no red be obtained at the first laying on of the pigment, it must be laid on a second time.

The sulphuret gives an intense colour with much greater certainty than the chloride of silver, for at a red heat it decomposes of itself, and can therefore produce its effect without the aid of the unglazing. The latter, however, is not prejudicial to it, and is only to facilitate the saturation of the glass by metallic vapours. The mixture of sulphuric acid has, in our opinion, no other object than this. Some sulphate or other is undoubtedly formed by the agency of this acid, which is decomposed in the red heat by the silica of the clay, and occasions the internal motion of the glass, whilst it affects its surface. This is what actually takes place in the unglazing of the glass, which unglazing we are convinced is effected by means of a mixture of sand and sulphate of lime.

The unglazing which is capable of facilitating the colouring of the glass by silver is not so great a change in the glass as to deprive it of all its transparency, but merely a slight modification by which its properties are uninjured. It is worth observing, however, that a piece of glass stained red in this manner does not possess the purity of colour which belongs to one coloured by copper. When the tone of colour is the same for both, that which was coloured by silver appears the darker.

Sulphuret of silver is prepared in the following manner: Pure silver is melted in a crucible, half its weight of sulphur is then introduced. The sulphuret of silver which is generally used is prepared by heating together 2 parts of silver and 1 of sulphuret of antimony.

Ochre Yellow.—The ochre yellow pigment is one of those fused pigments which are coloured by mixture. It receives its colour from the mixture of oxide of zinc and oxide of iron. This fused colour is a zincate of iron in which each atom of the one oxide is combined with an atom of the other oxide. This salt is obtained from sulphate of iron and sulphate of zinc precipitated with potash, soda, or their carbonates.

The persulphate of iron is prepared by dissolving 96 parts of protosulphate of iron in 100 parts of water, and adding half as much sulphuric acid as the salt already contains. The solution is heated to boiling, when small portions of nitric acid are introduced, until all nitrous acid has ceased to be disengaged. This operation may be explained in the following way :

The protoxide of iron contains

1 atom of iron	339.21
1 " " oxygen	100
1 " " acid	50.16
1 " " protosulphate of iron	910.37

The persulphate of iron consists of

2 atoms of iron	678.43
3 " " oxygen	300
3 " " acid	1503.18
1 " " persulphate of iron	2181.91

It is therefore necessary for the obtaining 1 atom of persulphate of iron to add to 2 atoms of protosulphate of iron 1 atom of sulphuric acid, that is to say, half as much as the salt already contains, and 1 atom of oxygen besides, which is supplied by the nitric acid.

The protosulphate of iron, when crystallized, contains 41 to 45 per cent. water, and the sulphuric acid of commerce contains only 81.68 per cent. pure acid. Consequently 18 parts of the sulphuric acid of commerce must be added to 100 of crystallized protosulphate of iron.

In order to form zincate of iron, so that each atom of the one oxide shall be combined with an atom of the other oxide, a solution of persulphate of iron and another of sulphate of zinc, both having the same weight on the areometer, must be prepared separately, and so much in volume must be taken from each, that the salt of zinc may be to that of iron as 2 to 5 ; or a solution of the salt of zinc, weighing 10° B., and

another of the salt of iron, weighing 25° B., may be mixed together in equal quantities. The precipitate which is then obtained by means of potash, or its carbonates, will contain in its composition the proper proportion; for sulphate of zinc consists of

1 atom of oxide of zinc	593.32
1 acid	501.16
1 sulphate of zinc	1094.48

The quantities of the sulphate of zinc and the sulphate of iron, each of which contains 1 atom of oxide, are in the proportion of 2 to 5.

When the oxides are precipitated by means of a fixed alkali any excess of the precipitating substance must be avoided, to prevent the oxide of zinc from being dissolved again. Just so much, however, is added as will produce a complete precipitation. The product is filtered, washed, and dried. Lastly, it is submitted to a red heat, in order to drive off the water which it contains. If the solutions of zinc and iron, after they have been poured together, are treated with an alkaline carbonate, the precipitate must in this case be heated to drive off the carbonic acid. The calcining is intended moreover to give stability to the combination of the two oxides. If it is required to colour a fused pigment by chemical combination or simple mixture, the object must be to obtain the colouring oxide in a state of the finest possible division. By this means, in the former case the combination takes place more easily, and in the latter the mixture is more intimate. Now calcining is always opposed to the direction we have given, for oxides condense by being calcined. This is also the case with the kind of pigments we have just been speaking of. On this account it answers to use the means which we recommended for obtaining the flesh-red; for they not only admit of compliance with the conditions which require calcining, but of the production of the colouring matter in a state of the finest division. We will now speak of the mixture of sulphate of potash.

The precipitate from the two oxides contained in the carbonates of zinc and iron is mixed with a concentrated solution of this salt; the liquor is evaporated, and the precipitate, when dry, is calcined at a dull red heat. It is then softened with water, placed in a filter which separates the zincate of iron from the solution of sulphate of potash: this precipitate is carefully washed and then dried.

This we consider to be the best process for the preparation of zincate of iron. The colouring matter which is obtained must now be united with the flux which serves as a vehicle for it. The best kind of flux for ochre yellow is No. 3 of the first class. They are mixed in the following proportions:

Zincate of iron	1 part.
Flux	4 parts.

As this fused pigment belongs to that class which is coloured by mixture, it ought not to be melted before it is used; we have, however, found it useful to frit it, *i. e.* to keep it at a dull red heat for some time; it is then levigated for use. In this way the colour becomes more beautiful and more transparent. This method should be employed principally in that kind of painting which the French glass-painters call *peinture par enlavage*.

Yellow from antimonite of lead. - The fused pigment which is coloured with antimonite of lead belongs to the foregoing class, inasmuch as it contains the colouring matter in a state of simple mixture. It is prepared by fusing in a crucible 1 part of antimonious acid and 3 parts of minium, levigating the product and mixing with it twice its weight of rocaille-flux, and then fusing the mixture again. This pigment has the fault of not being transparent. Therefore, although it is one of those which are coloured by mixture, it is advisable to melt it, in order to impart to it the greatest possible transparency. The quantity of flux must also be very small, for the oxide of lead being attracted by the flux is easily liberated from the antimonious acid, and the latter then gives only a feeble, opaque, white colour to the glass. The rocaille-flux is therefore preferred in this case also, because it is the most saturated, and consequently the least disposed to act upon the colouring matter.

The tint produced by antimonite of lead may be modified by adding some oxide of zincate of iron.

In order that it may be better understood what takes place in the process by which this colour is prepared, we may mention that at a red heat the antimonates are converted into antimonites.

Yellow from antimonite of iron.—The yellow obtained from this compound belongs to the same class as the two preceding. Like them it wants transparency, but it possesses a very rich colour, so that it can be used in many cases for mixed tints, and for the shading of green and brown. It is also of great use when employed alone.

Antimonite of iron is obtained through double decomposition, that is to say, by precipitating persulphate of iron with antimonate of potash. The product is washed, dried and calcined. Antimonite of iron is likewise prepared by direct mixture of antimonic acid with oxide of iron in the proportion of 4 to 1. This latter method admits of the relative quantities of the two compounds being varied at pleasure. The antimonite of iron, like the foregoing, is used with the rocaille-flux or with some flux of the first class. In the former case the mixture must be brought into a state of fusion, according to the treatment of the rocaille-flux in all other circumstances. In the latter case it is only levigated: 3 parts of flux to 1 of colouring matter are required.

We think it superfluous to speak of the pigments that can be prepared with the aid of the other yellow colouring materials which have been mentioned; they are little studied, and moreover are now in general used. It may be briefly stated, however, that in modern times the metal uranium has been used in Germany for the preparation of a yellow pigment. The process is as follows: Uranium ore is broken in pieces and roasted, dissolved in nitric acid, the solution filtered and the lead which is present in it precipitated by the addition of some drops of sulphuric acid. The clear green solution is then evaporated to dryness, and the salt is heated until it is converted into a yellow mass: 1 part of the substance so obtained is ground with 3 parts of a flux composed of 4 parts of minium and 1 part of powdered silica, fused together and levigated.

Of the Green.—The green pigment generally receives its colour from oxide of copper, oxide of chromium, and protoxide of iron, either separately, or by the combination of two or more with one another. The ingredients of this pigment are in combination with the flux. It is difficult to make its expansibility the same as that of the glass on which it is laid. The oxide of copper, even in a very slight quantity, alters this property in a great degree, and disposes the pigment to shell off the surface of the glass. The oxide of chromium does not partake of this quality in so remarkable a manner, but it requires a very fusible flux to dissolve it. Now this fusibility can only be obtained by mixing with the flux substances which modify its expansibility in the same way as oxide of copper does, and borate of soda in particular is one of these substances. The colour which protoxide of iron gives by itself is not rich enough, consequently this protoxide can never be employed

alone. In most cases it is used in combination with oxide of copper.

To colour a fused pigment green, the oxide of copper must be in combination with one or more acids of the flux, that is to say, it must be in the state of borate, silicate, or borosilicate. One of the fluxes which we have specified for the pigments of the second class seems best able to effect its solution, but the fluxes receive a degree of expansibility from the copper, which ill accords with that of the glass. Those fluxes therefore must be avoided which contain an abundance of acid, and those should be preferred which contain a large amount of base, especially of oxide of lead, although they possess less capability of being dissolved. Flint glass ^{*} (*fondant rocaille*) seems best adapted for this purpose, and yet no large proportion of oxide of copper can be mixed with it without producing the unpleasant result just stated. The green pigment is therefore best obtained from the following composition :

Minium	12 parts.
Silica	4 "
Oxide of copper	1 "
Red oxide of iron	1/8 part.

This pigment may be prepared in two ways :

1. The colouring oxides are melted in a crucible with the flux which has been previously prepared and ground together with them.
2. The oxides are fused together with the substances proper for the composition of the flux, after which the whole is well mixed and ground together.

It is not immaterial which of the two methods is employed ; we have always preferred the latter. In this method, when the mixture begins to be red-hot, the oxide of lead begins to melt, and dissolves the oxide of copper, while at the same time the latter is acted upon by the silica. This previous union of the two oxides is intended to separate the particles of the copper so as to dispose it to combine with the silica as soon as ever it is acted upon by it. In the former case, on the contrary, the oxide of copper is merely acted upon by the silica of the flux.

The foregoing receipt for the green pigments affords a colour of no great intensity, and we cannot expect to obtain a richer green by merely increasing the quantity of copper, for this, as

^{*} Bleiglas, lit. lead glass. This flint glass, the composition of which is given under the head No. 1 of the fluxes for pigments of the first class, will be found to contain more oxide of lead than the English flint glass.

we have just shown, could not be done with safety.^o Accordingly, in order to increase the respective proportions of the colouring oxides without risk, the composition of the flux must be modified at the same time by an addition to the quantity of oxide of lead.

Darker Green

Silica	1 part
Minnan	1-7 parts.
Oxide of copper	1 part.

‘ In these receipts we have no intention of laying down absolute proportions, for we well know that there are certain kinds of glass which will bear a greater quantity of oxide of copper without the colour shelling off. But we have endeavoured to impart such qualities to our pigments as will insure continual success, and consequently we have perhaps carried our caution to an extreme, rather than render the success doubtful.

Oxide of chromium does not answer so well for the green of the fused pigments as oxide of copper; for it seldom obtains so pure and bright a colour as the latter. Even if it is combined with very fusible fluxes it generally wants transparency, and yet the quantity of the substances which impart greater fusibility to the flux cannot be safely increased.

Oxide of chromium is mixed with one of the fluxes for pigments produced by combination, in the proportion of 1 part of oxide to 9 parts of flux, the same proportion that we specified for oxide of copper; and we are of opinion that it is better to heat the oxide of chromium with the elements of the flux than with the flux itself.

Notwithstanding what we have said concerning the properties of protoxide of chromium, it should not be neglected in the preparation of the pigments. As glass-painting frequently bears a certain degree of opacity very well, oxide of chromium may be employed with advantage, especially if it is only used for the colouring of a pigment by mixture. The green colour peculiar to it, which it possesses before it is united with a flux, makes it very well suited to this purpose, and the only problem now is to preserve it in a state of sufficiently fine division.

There are other substances which may be used for green pigments, but they give an opaque colour. Among these are zincate of cobalt, Rinnmann’s green, and antimonite of cobalt. Of course these compounds are not acted upon by the flux, and merely form pigments of the first class.

With respect to this matter we will describe a method

which, in our opinion, seems to promise manifold advantages. When it is required to mix oxide of chromium with a fused pigment containing lead, the neutral chromate of lead may be used, which furnishes at the same time oxide of chromium and oxide of lead, or at least a part of the latter. When this salt is submitted to a red heat it parts with oxygen and leaves behind a combination of the two oxides in the following proportions:

1 atom of oxide of lead	1391.6
1 " " chromic acid	650.7
1 " " neutral chromate	2042.3

And this gives after calcining,

1 atom of oxide of lead	1391.6
1 " " " chromium	502.2
1 " " plumbate of chromium	1893.8

It is evident that the oxide of chromium, which is thus held in combination with oxide of lead, must be in a state of most minute division, whereby its union with the silicates or borosilicates of the flux is facilitated to a remarkable degree. This pigment may be composed in the following way:

Silica	2 parts.
Muriatic	5 " "
Calcined borax	3 " "
Calcined chromate of lead	2 " "

These ingredients are melted and poured out.

The old glass-painters frequently availed themselves of the combined effects of yellow and blue, in order to obtain a green. Thus, for example, they gave to glass which had been coloured blue in the melting pot a yellow stain with the help of sulphuret of silver and the paste. This method is not in general use at the present day.

Of the Violet.—There are two modes of preparing violet pigments. The first consists in employing a colouring substance which is capable of producing a violet of itself; according to the second, the requisite violet is obtained by mixing a blue with a red pigment. The substances which are capable of bringing out a violet, without the assistance of another colour are the purple precipitate of Cassius and oxide of manganese.

We have already explained, in speaking of the red pigment, under what circumstances stannate of gold affords a violet colour, and have observed, that the purple of Cassius, whenever

it is decomposed before the fused pigment can dissolve its particles, produces a violet and even a blue, according as the change which takes place in it is more or less complete; and this happens in the case we are now speaking of. If 1 part of the purple of Cassius be mixed with 9 parts of one of the fluxes coloured by combination, without fusion, a violet pigment is obtained. This product is the effect of two causes which operate simultaneously, that is to say, the want of fusibility in the pigment, and the too great abundance of oxide of lead. Should the violet which is obtained in the manner we have just specified be not brought out with sufficient clearness, it may be still better developed by adding to the fluxes of the first section a little of flux No. 1.

Oxide of manganese gives an exceedingly deep violet colour, but, as we have elsewhere observed, it imparts to the pigments an extraordinary disposition to crack and shell off. This unfortunate property is easily overcome, however, by adding a large quantity of minium to its composition.

The composition should be as follows:

Silica	1 part.
Minium	6-8 parts.
Peroxide of manganese	$\frac{1}{2}$ part.

When this oxide of manganese is heated in contact with oxide of lead, it rapidly gives up oxygen, and is converted into sesquioxide.

This pigment is distinguished from the rest by this remarkable peculiarity, namely, that it can only be employed on condition that it is not painted on with any liquid, which, after the burning in, leaves a carbonaceous substance in its mass. This will be more apparent, when we remember that peroxide of manganese is used for whitening glass, on account of its property of extracting the carbon, which would impair its clearness. Here the carbon acts upon the manganese, deprives it of a portion of its oxygen, and converts it into a colourless protoxide, while it is liberated itself in the state of carbonic acid.

Now this would be the case if the pigment, at the moment of its liquefaction, contained carbon which was produced by the vehicle with which it was laid on the glass before the burning in. We would therefore recommend for this purpose a solution of borate of soda, instead of the gum or sugar water, and the thickened essence of turpentine, which are generally used.

The violet, which is obtained by a mixture of blue and red,

is prepared with common smalt and the purple of Cassius, the proportions varying at the discretion of the artist.

There is another violet, which is produced by the red oxide of iron, which is exposed to a white heat for some time; but it is almost entirely opaque, and produces on the glass only a kind of opaque and dull violet-grey. The pigment which is thus obtained is, nevertheless, of great use in glass-painting, and is prepared in the following way:

Violet oxide of iron	1 part.
Flux	3 parts.

No. 3. of the pigments of the first class is used for the flux.

Of the Brown.—The brown is an undefined colour, which may be prepared in a variety of ways, according to the requirements of the art, and the taste of the artist. We will describe the principal browns.

Zincate of iron, which contains one atom of zinc, and two of iron, gives a *yellowish brown*, which is frequently used. It is prepared in the same way as ochre yellow, except that the quantity of the salt of iron is doubled. For the composition we are now speaking of, the salt of zinc must be to the salt of iron as 2 to 10. The flux proper for this is the same as that which is used for the ochre yellow, and is also employed in the same proportions.

Zincate of iron, ochre yellow, as it is called, when mixed with either red oxide of iron or burnt sienna, gives a *reddish brown*, whose shade of colour varies with the proportions.

The same zincate of iron (ochre yellow) forms, with burnt umbré, a much *darker brown* than the preceding, and one which has no affinity to red.

Oxide of iron alone, when properly prepared, affords a *brown* of considerable utility. It is prepared in the moist way as follows: A solution of persulphate of iron is treated with an alkaline or carbonized oxide (with potash, soda, ammonia, or their carbonates); the precipitate which is obtained is either an hydrated oxide or a carbonate. It is placed in a filter, washed and dried, and then subjected to a red heat, in order to drive off the water or the carbonic acid. After this preparation the oxide of iron presents a brown colour, whose shade may be varied by heating it more or less. This oxide of iron bears no resemblance to that which is obtained in the dry way, although the calcining develops in it a more or less distinct red tone.

Burnt umber, when mixed with a flux, also affords a brown pigment.

A mixture of peroxide of manganese and oxide of iron likewise serves as a brown pigment of some utility. In order to prepare all these pigments, it is merely necessary to know that each of the colouring substances we have mentioned must be mixed with thrice its weight of flux No. 3 of the pigments of the first class.

No previous fusion is required. The colouring materials are merely brought into a state of the most intimate mixture by levigation together. The brown pigments are all pigments of the first class, and possess great opacity, but by virtue of this property they are exactly adapted to the use to which they are applied.

Of the Black.—The completely opaque pigments, whatever their proper colours may be, when laid upon glass, appear black in a transmitted light. The reason of it is this, viz. that a substance which allows no transmitted ray to reach the eye must cause a shadow, and consequently produce a black colour. Therefore either a black or an opaque colour may be used for the black lines of a drawing upon glass, or the parts that are in shadow. There is, however, a difference between the effect produced by a really black colour and that of any other colour not transparent.

When we look at a large transparent surface, *e.g.* a church window, besides the refracted rays transmitted through the glass, the eye receives also a few reflected rays, especially if the external light is not particularly intense. In this way the pigments, which only produce a black colour by virtue of their opacity, are slightly tinged with the colour which properly belongs to them. The black which proceeds from them thus loses its hardness, and falls more agreeably upon the eye. On this account pigments of *broken tones*, as they are called, are used for the black lines and shadows of a picture, and of these the brown pigments exhibit a great variety.

A pigment which shall appear black in a reflected as well as in a refracted light, may be prepared in two ways:

1. Opaque substances of a black colour may be mixed with a flux, *e.g.* oxide of iron, peroxide of manganese, peroxide of cobalt, and oxide of copper, in such considerable quantities as to prevent their vitrification taking place during the time of the burning in. A black pigment, by mixture, is thus obtained, which is composed of—

Oxide of copper	1 part.
Peroxide of manganese	1 "
Peroxide of cobalt	1 "
Oxide of iron	1 "
Flint glass	8—12 parts.

2. A black pigment by combination may also be prepared, and, after fusion, a certain quantity of oxide may be united with it, merely in the state of mixture, in order to render its opacity complete, as well as to impart to it the property of not splitting off in scales. This is therefore a combination of the two kinds of pigments. For the preparation of this compound, the following ingredients are melted in a crucible, in the following proportions :

Oxide of iron	2 parts.
Oxide of copper	2 "
Peroxide of manganese	1 part.
Flint glass	5 parts.
Fused borax	$\frac{1}{2}$ part.

As soon as the whole is melted, the contents of the crucible are poured out and levigated with

Peroxide of manganese	1 part.
Oxide of copper	2 parts.

The theory of the composition of this pigment may be explained in the following way : By fusing together oxide of iron, oxide of copper, and oxide of manganese, with the flux of flint glass and the borax, borosilicates are formed. The two former are green, and the latter are violet-red. Now green and violet-red, in proper proportions, give a black. The oxides which are afterwards added, as we have already stated, only render the opacity complete, and give the pigment a proper expansibility. The advantage of this latter circumstance is evident, when the effect of the oxides of copper and manganese upon expansibility is considered. If, on the other hand, it is required to prepare a pigment which shall only appear black in a reflected light, let the following ingredients be mixed together without being fused :

Black oxide of iron	1 part.
-------------------------------	---------

or even

Red or bright violet oxide of iron	1 part.
Flint glass or flux	2—3 parts.

When this colour is used, it appears black by a transmitted light, but by reflected light it assumes a reddish tint approaching to violet, less hard and more agreeable than black.

Of the White.—The white pigment is almost useless in

glass-painting. We shall, however, treat of it more fully than we should otherwise have done, in order to complete the series of the pigments of which we have here given a short account.

The white pigment has been used in modern times for ornamenting panes of glass with a kind of drawing whose whole effect depends upon the combination of the dull and opaque white of the pigment with the transparent glass, without the aid of any other colour. This branch of art, which borders a little upon the one we are treating of, seems, however, to have received no particular cultivation. The white pigment is a vitreous compound of more or less opacity, and this opacity is owing to the presence of zincic or antimoniac acid. This pigment is prepared according to the following process: An alloy is first made of 20 parts of tin to 80 parts of lead. The metal is melted in an iron ladle or a vessel of a similar kind, and the oxide which covers its surface is removed as fast as it is formed. When the entire mass has been converted into oxide, the calcining is continued a little while longer, while the oxide is stirred incessantly until it assumes a perfectly homogeneous appearance. It is then poured into a vessel full of water and well stirred, in order to effect the separation of the unoxidized grains of the alloy, which are mixed with the mass. These grains collect at the bottom of the vessel. The oxide is now dried and is fit for use. When this substance is mixed with potash, silica, and borax, in the proportions which we are about to specify, and then vitrified at a high temperature, a white pigment is obtained.

The white pigment of commerce that is used in enamel-painting may also be employed for the purposes of glass-painting, although it is rather deficient in fusibility. It is usually composed of the following ingredients:

Potash	1 part.
Oxide of lead	8 parts.
Silica	6 "
Stannic acid	6 "
Calcined borax	2 "

This enamel is also prepared by fusing together in a crucible the following ingredients:

Carbonate of potash	2 parts.
The oxides of tin and lead calcined	5 "
Silica	3 "
Borax	1 part.

As soon as the enamel has ceased to bubble, and appears in the state of a clear liquid, it is poured out. It must be melted

several times after being levigated, or at least pounded in a mortar. It is then freed from the excess of potash which it contains, and at the same time rendered whiter. The enamel of M. Clouet, as a specimen of an enamel coloured by antimonious acid, may be contrasted with the above. It is prepared from

White glass	12 parts.				
Uncalcined borax	4				
Salt-petre	1 part.				
Purified antimonium dypboricum	4 parts.				

This is a quadruplicate borosilicate of lime, potash, soda, and alumina.

It is less adapted to painting on glass than the one we have mentioned before, and more disposed to scale off, since it is deficient in oxide of lead.

We recommend the following enamel, which seems to contain the qualities requisite for painting on glass. Its composition is as follows:

Silica	3 parts.				
Calcine*	7½				
Calcined borax	2				

The ingredients are melted, and then poured out.

The old glass-painters frequently used white pigments of the similar in composition to those which we call pigments of the first class. Levigal prepared a white pigment by mixing sulphate of lime (gypsum) with rocouille-doux (flint glass). Egibien, Hammequer de Blanmont, and the Abbot of Marcy propose the same substance, but with a different enamel. Flint, pulverized rock-crystal, and the powder of calcined bones, have also been used for this purpose: a better result would have been obtained with stannic acid employed in the same way.

Calculation of the atomic weights of the pigments.—Now that we have shown that the various kinds of glass are composed of several siliates in definite proportions, probably in combination with one another, the study of their atomic weights must on this account be the more interesting. Moreover, if we would employ ourselves in making satisfactory inquiries into the art of composing the pigments, this cannot be done with any success unless we are acquainted with the calculation of the atomic weights which are made use of in these compositions. We will therefore communicate an easy method of determining * By calcine is meant the calcined oxide of an alloy of 20 parts of tin and 80 of lead.—(Author's note.)

the composition of a pigment, or any other kind of vitreous substance, according to the atomic weights as follows:

Silicic acid	192.6	Se. Sesquioxide of manga-	
Boric acid	435.98	nese	1011.5
Oxide of aluminum	613.33	Peroxide of manganese	555.7
Oxide of calcium	356.03	Stannic acid	935.29
Oxide of potassium	587.91	Antimonious acid	1006.4
Nitrate of potash	1264.93	Oxide of zinc	503.32
Oxide of sodium	390.92	Oxide of cobalt	469.
Subcarbonate of soda	666.25	Peroxide of cobalt	1038.
Borate of soda	1262.88	Oxide of chromium	1003.
Oxide of manganese	1467.	Oxide of copper	495.6
Oxide of iron	978.	Protoxide of lead	1394.5

When it is required to determine the number of atoms of each of the bodies which are used for a pigment whose composition is known, each of the expressions of the formula must be multiplied by one and the same number, *e.g.* 100, 1000, or 10,000, just as it may happen to be necessary, in order to enable us to divide all these expressions by the atomic weight of the substance which they represent.

Let a pigment, for example, be composed of

Silica	45 parts.
Potash	6 "
Oxide of lead	70 "

If only the two first expressions of the formula were considered, it would be sufficient to multiply them by 100; for the products would be divisible by the atomic weight of the silica (192.6) and that of the potash (587.9). But it is evident, that they must be multiplied by 1000 in this case, on account of the third expression. Accordingly we get

Silica	45,000 divisible by	192.6
Potash	6,000 " "	587.9
Protoxide of lead	70,000 " "	1394.5

If the division is performed, the following result is obtained:

Silica	210 atoms, or 24
Potash	10 " " 1
Protoxide of lead	50 " " 5

Consequently, if every atom of these bodies contains 100 parts of oxygen, the quantities of this gas will be to one another as the atoms themselves, namely:

Silica	2,400 or 24
Potash	100 " 1
Protoxide of lead	500 " 5

The oxygen of the acid is four times as much as that of the bases. A double quater-silicate thus appears. The oxygen

of the potash is moreover to that of the oxide of lead as 1 to 5, and consequently we have 1 atom of the quater-silicate of potash and 5 atoms of the quater-silicate of lead.

To compose an enamel, then, which shall contain 5 atoms of silicate of lead and 1 atom of silicate of potash, we must take

$$\begin{aligned} 5 \text{ atoms of oxide of lead} &= 1391 \times 5 = 6976 \\ 1 \text{ atom of potash} &= 587 \times 1 = 587 \end{aligned}$$

Further, if it be required that these bases should form with the silica quater-silicates, we must take as many atoms of silica as are necessary, in order that the latter may contain four times as much oxygen as the bases. Now if the oxygen of the bases amounts to 6, we get for the silica $1 \times 6 = 24$.

$$24 \text{ atoms of silica} = 192 \times 24 = 4608$$

By simplifying the expressions we obtain at length

Protoxide of lead	70 parts.
Potash	6 "
Silica	15 "

In order to obviate the necessity of making calculations, we have drawn up Tables, by the assistance of which the reader may discover at the first glance the quantity of any body which corresponds to a given number of atoms.

<i>Silicic Acid.</i>	
Atoms.	Parts.
5	1
10	2
15	3
20	4
25	5
30	6
35	7
40	8
45	9
50	10

<i>Oxide of Potassium.</i>	
Atoms.	Parts.
1	0.6
2	1.2
3	1.8
4	2.3
5	2.9
6	3.5
7	4.1
8	4.7
9	5.3
10	5.9

<i>Phosphoric Acid.</i>	
Atoms.	Parts.
1	0.4
2	0.9
3	1.3
4	1.7
5	2.2
6	2.6
7	3.0
8	3.5
9	3.9
10	4.0

<i>Subcarbonate of Potash.</i>	
Atoms of Potash.	Parts of the sul- carbonate.
1	0.9
2	1.7
3	2.6
4	3.4
5	4.3
6	5.2
7	6
8	6.9
9	7.4
10	8.6

Nitrate of Potash.

Atoms of Potash.	Parts of the Nitrate.
1	1.3
2	2.5
3	3.8
4	5.
5	6.3
6	7.6
7	8.8
8	10.1
9	11.4
10	12.6

Oxide of Sodium.

Atoms.	Parts.
1	0.4
2	0.8
3	1.2
4	1.6
5	1.9
6	2.3
7	2.7
8	3.1
9	3.5
10	3.9

Borate of Soda.

Atoms of Boracic Acid.	Atoms of Soda.	Parts of the Borate.
2	1	1.3
4	2	2.5
6	3	3.8
8	4	5.
10	5	6.3
12	6	7.6
14	7	8.8
16	8	10.
18	9	11.3
20	10	12.6

Subcarbonate of Soda.

Atoms.	Parts.
1	0.7
2	1.3
3	2.
4	2.7
5	3.3
6	4.
7	4.7
8	5.3
9	6.
10	6.7

Oxide of Calcium.

Atoms.	Parts
2	0.3
	0.7
3	1.1
4	1.4
5	1.8
6	2.1
7	2.5
8	2.8
9	3.2
10	3.6

Oxide of Aluminum.

Atoms.	Parts
1	0.6
2	1.3
3	1.9
4	2.6
5	3.2
6	3.8
7	4.5
8	5.1
9	5.8
10	6.4

Protoxide of Lead.

Atoms	Parts.
1	1.
2	2.8
3	4.3
4	5.6
5	7.
6	8.4
7	9.7
8	11.1
9	12.5
10	14

Minium.

Atoms of Protoxide.	Parts of Minium.
1	1.4
2	2.8
3	4.3
4	5.7
5	7.1
6	8.5
7	10.
8	11.4
9	12.8
10	14.3

The difference between nitium

and protoxide of lead is so considerable, that it may be perceived at once in any given number of atoms, as will appear from a comparison of the two Tables.

Protoxide of Manganese.

Atoms.	Parts.
1	1
2	2
3	3
4	4
5	5
6	6
7	7.1
8	8.1
9	9.1
10	10.1

Deutoxide of Manganese.

Atoms.	Parts.
1	1.5
2	2.9
3	4.4
4	5.9
5	7.3
6	8.8
7	10.3
8	11.7
9	13.2
10	14.7

Peroxide of Manganese.

Atoms of Protoxide.	Parts of Peroxide.
1	1.1
2	2.2
3	3.3
4	4.4
5	5.5
6	6.7
7	7.8
8	8.9
9	10
10	11.1

Peroxide of Manganese.

Atoms of Deutoxide.	Parts of Peroxide.
1	1.7
2	2.3
3	3
4	4.7
5	5.3

Atoms of Deutoxide.	Parts of Peroxide.
6	10
7	11.7
8	13.3
9	15
10	16.7

These two latter Tables show the quantities of peroxide of manganese which are necessary to produce by their decomposition a given number of atoms of protoxide or deutoxide.

Oxide of Zinc.

Atoms.	Parts.
1	0.5
2	1
3	1.5
4	2.0
5	2.5
6	3
7	3.5
8	4
9	4.5
10	5

Oxide of Iron.

Atoms.	Parts.
1	1
2	1.7
3	2.9
4	3.9
5	5
6	5.9
7	6.9
8	7.8
9	8.8
10	9.8

Protoxide of Cobalt.

Atoms.	Parts.
1	0.5
2	1.3
3	1.4
4	1.9
5	2.3
6	2.8
7	3.3
8	3.7
9	4.2
10	4.7

<i>Peroxide of Cobalt.</i>	
Atoms of Protoxide.	Parts of Peroxide.
1	0.5
2	1
3	1.5
4	2.1
5	2.6
6	3.1
7	3.6
8	4.1
9	4.7
10	5.2

The Table of the peroxide of cobalt has been composed on the same principle as that of the peroxide of manganese.

<i>Oxide of Chromium.</i>	
Atoms.	Parts
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10

<i>Oxide of Copper</i>	
Atoms	Parts
1	0.5
2	1
3	1.5
	2
	2.5

Atoms.	Parts.
6	3
7	3.5
8	4
9	4.5
10	5

<i>Antimonious Acid</i>	
Atoms.	Parts.
1	1
2	2

<i>Antimonic Acid.</i>	
Atoms of Antimonious Acid.	Parts of Antimonic Acid.
1	1
2	2.1
3	3.2
4	4.1
5	5.3
6	6.5
7	7.4
8	8.4
9	9.5
10	10.5

<i>Stannic Acid.</i>	
Atoms	Parts.
1	0.9
2	1.9
3	2.8
4	3.7
5	4.7
6	5.6
7	6.5
8	7.5
9	8.4
10	9.3

In order that we may make no mistake in laying down the proportions of the oxygen of the base to that of the acids, we must remember that these compositions contain different quantities of oxygen to one atom, namely:

	Parts.		Parts.
1. Boracic acid	300	7. Stannic acid	200
2. Alumina	300	8. Antimonic acid	500
3. Sesquioxide of manganese	400	9. Antimonious acid	200
4. Protoxide of manganese	300	10. Oxide of chromium	300
5. Peroxide of manganese	200	11. The other bodies	100
6. Oxide of iron	300		

Before we conclude the chemical part of our subject, we wish to direct the attention of those who are engaged in the preparation of pigments for glass-painting to a series of compositions which are capable of being used with very great advantage in the art. We wish to speak of certain combinations of the colouring oxides with one another, about which we have at present said very little. Further back, where we were speaking of the colouring substances in general, we expressed our opinion concerning these kinds of compositions, which we likewise admitted into the class of salts. We have already had occasion to consider a certain number of these combinations which are very much used in the manufacture of the pigments, and we now intend to impart what information it is in our power to give upon a few other matters less known, but which seem capable of affording valuable resources to the art of painting on glass; and lastly, we intend to point out those particulars which, in our opinion, deserve to be studied. We wish to open to fresh observers a fruitful field, full of objects both useful and interesting, and we only regret that it was not our lot to explore it ourselves.

The most stable amongst the combinations which the indifferent oxides are capable of entering into with the basic oxides, are the following:

Protoxide of manganese and oxide of iron;
 Protoxide of manganese and peroxide of cobalt;
 Protoxide of manganese and oxide of copper;
 Protoxide of manganese and oxide of CaO and BaO ;
 Protoxide of manganese and oxide of zinc;
 Oxide of iron and peroxide of cobalt;
 Oxide of iron and oxide of copper;
 Oxide of iron and oxide of chromium.

Amongst all the other possible combinations of the colouring metallic oxides with one another, there are a few more of great stability, although certain of the oxides out of which they are formed are remarkably deficient in this stability. Thus, amongst other combinations, there are a cuprate and a plumbate of silver, of which the oxide of silver is reducible at less than a red heat, and further, a manganate of silver, which appears to possess the same property.

Protoxide of manganese and oxide of iron combined in equal atoms.—First process: Two solutions, both of equal weight, according to Beaumé's areometer, one of protosulphate of iron, and the other of protosulphate of manganese, are mixed together; they are then raised to the boiling point, and

treated with an excess of carbonate of soda. The precipitate, after it has been washed and dried, is moistened with nitric acid, and exposed to a red heat in a crucible, until it is perfectly decomposed. This operation explains itself, and we need merely remark, that these sulphates contain equal quantities of protoxide, and that both the protoxides are converted into sesquioxides, and give an equal number of atoms.

<i>Protosulphate of Iron.</i>		<i>Protosulphate of Manganese.</i>	
2 at. protoxide	878.12	2 at. protoxide	911.4
2 at. acid	1002.32	2 at. acid	1002.32
<hr/>		<hr/>	
2 at. protosulph. iron . .	1880.44	2 at. protosulph. mang. .	1913.72
<hr/>		<hr/>	
<i>Sesquioxide or Peroxide of Iron.</i>		<i>Sesquioxide of Manganese.</i>	
2 at. protoxide	878.12	2 at. protoxide	911.4
1 at. oxygen	100.00	1 at. oxygen	100.00
<hr/>		<hr/>	
1 at. peroxide	978.12	1 at. sesquioxide	1011.4

Second process: A stream of chlorine gas is caused to pass through water with which carbonate of manganese, or the oxide obtained by precipitating sulphate of manganese with potash, has been mixed. The oxide which is obtained in the state of hydrate is mixed in proper proportions with hydrated oxide of iron, and exposed to a red heat.

<i>Hydrated Peroxide of Iron.</i>		<i>Hydrated Peroxide of Manganese.</i>	
2 at. iron	678.15	2 at. manganese	711.5
3 at. oxygen	300	1 at. oxygen	100
Water	168.70	Water	150
<hr/>		<hr/>	
1 at. peroxide	1147.15	1 at. peroxide	1261.5

The following result is obtained by heating the mixture:

<i>Anhydrous Peroxide of Iron.</i>		<i>Anhydrous Sesquioxide of Manganese.</i>	
2 at. iron	678.15	2 at. manganese	711.5
3 at. oxygen	300	3 at. oxygen	300
<hr/>		<hr/>	
	978.15		1011.5

These hydrates, it is evident, must be mixed together in equal parts.

Protoxide of manganese and peroxide of cobalt.—This combination is obtained by precipitating with an alkali, as in the case of iron, from a solution of sulphate of manganese and sulphate of cobalt, in equal quantities and of equal density, and calcining the precipitate merely at a red heat. The atoms

of the acids are here likewise combined in equal proportions. We have assumed these proportions for all analogous combinations.

Protoxide of manganese and oxide of copper.—The composition is prepared in the same way as the foregoing; but it is better to effect the precipitation from the sulphate of copper and sulphate of manganese with an alkaline carbonate, because the oxide of copper is very likely to be re-dissolved if an alkali is used. Moreover, the proportions of the solutions must be equal. We may proceed in the same way in the calcining; it is as well, however, to add a little nitric acid to the mixture, to render the oxidation of the manganese complete.

Protoxide of manganese and oxide of chromium.—This combination arises from pouring chromate of potash into a solution of sulphate of manganese. The protoxide of manganese is oxidized at the expense of the chromic acid, which is thus transformed into oxide of chromium.

Protoxide of manganese and oxide of silver.—This combination arises from heating a mixture of peroxide of manganese and metallic silver, which has been precipitated with copper from a solution of nitrate of silver.

Oxide of iron and peroxide of cobalt.—This is obtained from a mixture of solutions of sulphate of iron and sulphate of cobalt, which are treated with an alkaline subcarbonate, in order that the precipitate which is thus obtained may be calcined.

Oxide of iron and oxide of copper.—The same process as before.

Oxide of iron and protoxide of copper.—A mixture of oxide of copper and finely triturated iron filings is subjected to a red heat. The copper returns into the state of protoxide, and gives up its oxygen for the iron to form an oxide with it. Probably it would be necessary, in using this compound as colouring matter, to keep it carefully from the air as soon as it passes into a liquid state. We may avail ourselves of this composition for colouring glass red, but it is probable that in this case there is no combination between the two oxides.

Oxide of iron and oxide of chromium.—This combination takes place when a solution of protosulphate of iron is treated with chromate of potash. The protoxide of iron is brought into a higher state of oxidation by means of the oxygen which the chromic acid gives up, and the chromic acid is thereby reduced to the state of oxide of chromium.

Protoxide of copper and oxide of silver.—This combination

is obtained by heating in a crucible oxide of copper with metallic silver in the form of powder. The same phenomena may be observed here as in the case of iron and copper.

Plumbates.—We have already mentioned the fact, that oxide of lead to a great degree possesses the property of combining with the other metallic oxides. The combinations into which it enters with them are particularly valuable, although for an entirely different reason from that for which the similar compounds of which we were just now speaking are valuable; they are valuable, because the oxide of lead imparts a very slight stability to them. But while it combines with the oxides, it dissolves them, separates their particles, and facilitates in a remarkable manner the vitrification of those pigments which are coloured by combination.

The most important of the plumbates are those of cobalt, copper, and manganese, which are prepared by subjecting minium with the oxides of one or other of these metals to a red heat.

CHAPTER III.

THE MECHANICAL PART OF GLASS-PAINTING.

Preparation of the colours for use.—We shall now distinguish the colouring materials, when combined with their fluxes, by the epithet *colour*.

The colours must first be reduced to an extremely fine powder, by long-continued levigation upon porphyry, or in a mill of porcelain biscuit, constructed expressly for this purpose, which we shall describe hereafter. In order to do this, it is necessary to mix with it a sufficient quantity of pure water; it is then dried and put away in well-stopped bottles.

The levigated colours, at the time when they are used, are mixed with liquids of various kinds, but all for the purpose,—1. of giving them sufficient stickiness and consistency, so that they may not run on the surface of the glass;—2. of causing them to adhere sufficiently, when dry, until the time when they are fixed by the firing;—3. of adapting them to the various kinds of paint-brushes which are generally used in glass-painting.

These liquids are usually—water, oil of turpentine, and oil of lavender, somewhat thickened by the substances which are

to fix the colours, after they are dry, upon the glass. Thus, for example, sugar-candy or borax are generally mixed with water; thickened oil of turpentine and oil of lavender to the oils of turpentine and lavender. This inspissation is produced by a longer action of the air upon these essential oils or essences. Among the preparations which are brought under the name of thickened essence of turpentine, &c., we must distinguish between those which have been really thickened by the action of the air, and those which are nothing more than the residue after the distillation of the ordinary essences of turpentine and lavender. A residue like this will never answer our purpose well, and we might just as well use turpentine, or even varnish. But it will be explained hereafter why liquids of this kind must be rejected.

The *fat*, or thickened essence, as it is called, is obtained by exposing to the air and light one of the above-mentioned essential oils in a glass vessel with a wide mouth, which must be covered with a woven texture that will allow the air to pass through without difficulty. The contents are stirred from time to time, and the essential oil has attained to the proper degree of inspissation when it is of the consistency of a thick syrup.

The water colours and the essential oil colours may both be advantageously employed, and they are frequently used alternately in one and the same painting.

The implements with which the colours are laid on glass are various sorts of paint-brushes; viz.

1. *Marten's-hair pencils*, brushes which run to a fine point, and are generally used for water-colour painting.

2. *Fitch pencils*.—These are not finely pointed, but cut off abruptly at the lower part, so that they present a flat surface perpendicularly to their length.

3. *Broad badger's-hair pencils*.—These are broad and flat brushes for softening the colours.

4. *Stockfish-tails*, of soft hog's bristles, of the same form as the foregoing.

5. *Hard pencils*, of the same form as the fitch pencils, only prepared from hog's bristles.

6. *Hog's-bristle pencils*, such as are used for oil-painting.

Use of these pencils.—In order to lay an uniform coating of colour upon the glass, a marten's-hair pencil must be used when the space which has to be covered is small; if, on the contrary, it is large, either a stockfish-tail, or a cut badger's-hair pencil, must be used. By the help of these implements,

the colour is laid on the glass and spread over its surface by being rubbed in one direction, and then in the opposite, until the whole coating is uniform. Painting of this kind has generally furrows or channels which are caused by the hairs of the pencil, but these may be removed when it is considered necessary, by means of a fitch pencil, or, still better, by means of a cut badger's-hair pencil.

The fitch pencil, as we have stated, is terminated by a flat surface, and it is used for touching the glass with the ends of its hairs, but not for drawing over the surface, as is the case with the other pencils. If this is done skillfully, and continued for a sufficient length of time, not only will the streaks thereby disappear, but the colour will also be diffused uniformly over the whole of the surface which is to be covered. The pencil must, however, be used until the colour is almost dry, and a very short time before this takes place the colour will be distributed with perfect uniformity.

The fitch pencil answers very well for laying on thin coatings of *ver.* liquid colour, when they are required. A little colour is taken with the pencil from the palette, and lightly dabbed on those parts which are to be covered with the colour.

The marten's-hair pencil, on the contrary, is used for laying on those colours which are required to be fused, for marking the lines, &c.

The hard pencil, of the same form as the fitch pencil, is used for removing certain water-colours which were previously laid on the glass, in order to execute in this way a species of painting of which we shall presently speak more fully.

For mixing up the colours properly, certain precautionary measures are necessary. When a colour is to be mixed with an essential oil, for example, a little of this colour, which, as we have before stated, must have been previously well levigated and dried, is put upon a palette and mixed, by means of a spatula, with a sufficient quantity of thickened essence to allow of its being worked to a stiff paste. It is then diluted with more or less essential oil of turpentine, according as the colour which is to be laid on is intended to be of a more or less rich tone; it is then ground a little more in the mill, and used in the manner above described. These precautions are especially important towards insuring a successful use of the fitch pencil.

The process is the same with regard to the water-colours, except that instead of a thickened essence a thick syrup is used, and instead of essential oil of turpentine, water. The

object of this method of operation is to determine the proportion of sugar or thickened essence without difficulty. For the borax colours, and even for those in which pure essence of turpentine is used, we are limited to the employment of as much liquid as will yield a thick paste. As a general rule, the enamel colours should not be much moistened.

It is not immaterial whether a water-colour or an oil-colour, and whether essence of turpentine or essence of lavender, be used. The water-colours are, generally speaking, more liquid than the oil-colours, under circumstances in other respects the same. They have less consistency, and consequently do not admit of being softened so well with the paint-brush. On a large surface of paint, the oil-colours are much better adapted to forming an uniform layer of colour, and the streaks and furrows which the stockfish-tail leaves behind may be more easily removed by means of the cut badger's-hair pencil. The use of the fitch pencil also insures a far more satisfactory result with oil-colours, and consequently these colours are preferred in all cases which are analogous to the above.

In comparing the essence of lavender with the essence of turpentine, we find that the latter dries much sooner than the former; the former, therefore, is employed whenever a liquid which is long in drying is required. It is not used alone in the preparation of the colours, but as much of the essence of turpentine is mixed with it as is necessary to cause it to dry at the proper rate. These means are employed when the fitch pencil is to be used for softening, which always requires time. In the water-colours we cannot advantageously substitute for sugar other viscid substances, *e. g.* gum, &c.; for the former has the advantage of being much softer, and at the same time is not so liable to peel off.

Two styles of execution essentially different from each other are adopted in glass-painting. That which in former times was chiefly employed, namely, the Gothic, consisted in using no enamel for colouring the glass, but in merely marking the outlines and shadows with a brown opaque pigment upon glass which had been coloured in the melting-pot. This style of painting, or rather of drawing, notwithstanding its simplicity, is susceptible of the most beautiful effects which the decoration of panes of glass is capable of producing. To it we are indebted for the beautiful Gothic windows which adorn our old churches. This style of glass-painting is moreover the easiest of execution, for the artist need only be a skilful draughtsman.

and has occasion for nothing else, except one single pigment, which is easily prepared, and not at all difficult to use.

The second style belongs to the period of the revival of glass-painting; it supposes likewise the use of coloured glass, but at the same time requires the use of numerous pigments, by means of which the artist executes a real painting on the glass, which, in regard to its effects, may be compared with oil-painting. The artist is therefore under the necessity of having a palette covered with vitrifiable colours, which is of the same use to him as a palette supplied with oil-colours is to the oil-painter. The execution of this style is difficult, and requires a particular study.

Glass-painting, taking it altogether, presents numerous and considerable difficulties, which proceed from the nature of the colours and of the glass itself, either in relation to the mechanical application of the pigments, or in relation to the realization of the results which the artist endeavours to obtain. We will mention the kinds of manipulation which are necessary in the various cases.

The smooth and polished surface of glass is not very favourable to the laying on the colours. When we are laying any colour on the glass, a second stroke of the brush frequently takes off what the first had deposited; and thence arises the impossibility of hesitating in this work. This difficulty has disposed some artists to paint only on glass whose smooth surface has been removed by sandstone or emery.

But the greatest obstacle to the painter arises from the nature of the vehicle, which does not easily admit of the several coatings of colour being laid one over the other, which, on account of the substances that are used, do not even adhere after the first coating is thoroughly dry. As the vehicle for fixing on the first coating retains its solubility, it is capable of being softened and removed from the surface by the succeeding coatings. To meet this difficulty it was happily suggested that the vehicle should be changed in every coating of colour which was laid on over another. Thus, for example, we paint with water-colour upon an oil-colour, and *vice versa*, with oil-colour upon a water-colour. The fixing substances of the one colour being insoluble in the liquid of the other, there is no danger of removing, by a second application of the colour, that which has been produced by a first.

The inconvenience, however, which accompanies the employment of colours prepared in different ways, gave rise to the discovery of a method by which we may paint with the same

vehicle. This discovery was arrived at by observing the following fact. An oil-colour, rendered viscid with thickened, essential oil of turpentine, or Venice turpentine, retains its solubility in this liquid, if it has been dried by exposure to the air; but if the painted pieces of glass have been submitted to a moderate temperature in a drying-oven, the colour loses its easy solubility, bears the friction of the pencil very well, and the fresh coatings may be laid on without difficulty.

In proceeding according to the method which we have just described, the painter will sometimes have occasion to interrupt his work, in order to dry the painted pieces of glass in the oven; and this circumstance was so disagreeable to many artists, that they considered how they might avoid the necessity of doing so, and at length they succeeded in painting on glass with water or oil colour, as is the practice in painting on canvas, without being obliged to dry the first painting. We must observe, however, that this is to be attributed more to their skill and dexterity, than to the method itself to which they ascribe this invaluable superiority in practising their art. In order to explain their method of proceeding, we will consider a painting with water-colours. The artist first of all makes up his colour, and mixes with it no more sugar than is necessary to cause it to adhere. This colour laid on, he paints upon the first coating with colours which contain more dissolved sugar, without being thereby of a thicker consistence. The increasing solidification of the vehicle prevents its solvent action, upon the colour which was originally laid on.

If this is dexterously performed, it admits of the painting being *impasté*, to use a technical expression. Nothing but long experience and perfect dexterity will—we repeat it—enable us to employ this method with advantage.

For the execution of paintings on glass, particularly Gothic, a method as simple as it is ingenious is frequently had recourse to, which enables the artist to work with the greatest certainty of success. This mode of painting is designated by the French term *peinture par entourage*, and consists in drawing the outlines with an oil-colour, and painting over the whole with a water-colour, which, after it is perfectly dry, is to be removed with a hard paint-brush. By a dexterous use of this paint-brush, portions of colour of different degrees of thickness are removed, according as shadows, half-tints, or lights are required. Wherever the glass is left bare by a complete removal of the colour, we get the lights; the places which the brush has spared give the shadows, and the half-tints are pro-

duced by an imperfect removal of the colour. In this way the process of laying on the ground-colour of the picture is performed, and after the latter has undergone the firing, it is again painted over, and retouched with a colour which has been made up with sugar or thickened essence.

The colour proper for the *peinture par enlavage* is an enamel colour, with which a little borax is mixed, and which is then levigated with enough water to give a thick paste. The colour is laid on by means of a stockfish-tail, and softened uniformly with a cut badger's-hair pencil, with the assistance of which the colour is easily spread over the glass. The small quantity of borax which has been mixed with the colour causes a sufficient adhesion of the latter to the glass, so that the hard pencil may be fearlessly applied to the removal of the water-colour.

The majority of the pigments of the second class are well adapted to the employment of this method. There are, however, among the pigments of the first class, some whose colouring matter is acted upon by borax, so that a combination arises which imparts to the colour which has been laid on too much adhesiveness to admit of its being removed with the hard pencil. Among these colours are ochre yellow and all those pigments which contain oxide of zinc.

This unpleasant circumstance may, however, be certainly obviated by fritting these pigments before they are levigated for mixing with borax.

To *frit* a pigment is to heat it to that point at which it coagulates, and, by reason of an incipient fusion, forms a mass of the consistency of dough.

Pigments of the second class are seldom used for the *peinture par enlavage*. As this kind of painting only has in view a simple sketch upon a previously coloured ground, it requires in most cases merely an opaque pigment coloured by mixture. That which is best adapted to this purpose consists of a flux of flint glass and of brown or violet oxide of iron in the usual proportions, with a mixture of calcined borax, whose weight is equal to the eighth part of that of the flux. The proportions of the borax and the flux are calculated for the preparation of flux No. 3 of the pigments of the first class.

The method which we have just described is capable of an important modification with respect to the preparation of the colour proper for *peinture par enlavage*. Instead of dissolved borax, merely the oil of turpentine of commerce is used. In this case, the drawing is first sketched with a pen in water-

colour, and a coating of oil-colour is laid on over it. This modification is based upon the property which essence of turpentine possesses of giving sufficient firmness for the *enlevage* pencil to be used. The essence of turpentine owes this property to a small quantity of resin which it contains, but which is not to be found in it after it has been rectified by a new distillation. Hence it follows that this method is the opposite to the former. Certain precautionary measures, however, ought not to be neglected, to obtain a successful result. The water-colour must accordingly be properly mixed with sugar, so that the oil-colour may be incapable of softening it. Moreover, after the oil-colour is laid on, it must be submitted in the drying-oven to a temperature sufficient to produce the requisite firmness. It is also necessary to avoid adding essence of turpentine frequently to the same colour, because the proportion of resin is likely to be increased by that means, and the consequence would be too strong an adhesion of the pigment to the glass, so that it could not then be easily removed with the *enlevage* pencil.

Circumstances arise in which this method is rather complicated, and this is the case when it is required to paint upon glass which has not been coloured. In order to paint a head, for example, a light tint is laid on for the colouring of the lights, and upon this a coating of colour suited to the *enlevage*, in order to form the shadows and half-tints. Thus, upon a drawing prepared with water-colour, the first coating must be laid on with a colour mixed with thickened essential oil, and the second with a colour mixed with borax; but if the drawing has been executed in colour mixed with thickened essential oil, the first coating of paint must be laid on with colour mixed with sugar-water, and the second with colour moistened with pure essential oil, in conformity with the directions we have given above.

The *peinture par enlevage* is not only simple, but is also executed in a very short time. It is peculiarly adapted to decoration, especially to the execution of such designs as stand out in light colours from a dark ground, and to the representation of the embroidered parts of drapery. In this case the *enlevages* are executed in a different way. To make the drawing clean and correct, wooden scrapers of various forms must be substituted for the hard pencils. The colour which is here operated upon is of no particular kind, but may be any pigment whatever that has been levigated with thickened essential oil.

Finally, glass-painting justifies every possible artifice the

object of which is to lessen difficulties, or to enable us to obtain results which are not to be obtained in any other way. Thus, for example, it is not uncommon to paint both sides of the glass, in order to obviate the unpleasant results of laying on one colour over the other. The same method is adopted in the case of yellow from silver, because the substances by which it is produced ought not to be brought into immediate contact with the colouring enamels. In this way a green is obtained, that is to say, by giving a yellow stain to the back of a piece of glass which has been painted blue.

The same method is also followed in order to impart brilliancy and a remarkable freshness to the brownish red colours from iron; that is to say, a yellow is applied to the opposite side of the brown.

Whatever method be adopted, the employment of the colours is always, however, subject to certain restrictions. Care must be taken to use as few mixtures as possible. The colours are by means of the latter mutually destroyed at the temperature at which they are burnt in, while at the same time new combinations take place. By avoiding a mixture of the pigments we obtain purer, less perishable, and much more certain colours. It is better to lay one colour over the other, instead of mixing them. In order, therefore, to produce an effect similar to that which may be obtained with ochre yellow and red from iron, the yellow is first laid on and then tempered with red.

It is also of consequence to lay on the pigments as thin as possible, and there are several reasons for so doing. Thus if the colours are laid on too thick, the adhesive substances that are in them form a mass which possesses too little softness and flexibility. The motions caused by expansion, which the glass undergoes in the changes of temperature, unless they are shared by the painting, at length overcome the adhesion of the colours and loosen them from the surface of the glass. This always takes place when water-colours and oil-colours are laid on in alternate coatings, for the heterogeneous qualities of the substances by which those colours are fixed are still more conducive to this result. The mere drying of itself is often sufficient to produce this unpleasant result in consequence of the unequal contraction of these substances.

On the other hand the water-colours certainly part with the water they contain, in drying on the glass, but then they retain the sugar which was mixed with them; the oil-colours give up the volatile part of their vehicle, whilst the thickened essence which is in the latter has lost the power of being con-

verted into vapour, and consequently remains upon the glass. Hence it follows, that these substances must be consumed in the firing, and leave a certain quantity of carbon lying between the particles of the pigment. The body re-acts upon certain combinations, *e. g.* the oxides of iron and lead, which it turns black by robbing them of their oxygen, which it does so much the more, as the carbon being protected by a thick coating of colour resists combustion the longer. This circumstance is at least of importance with regard to the flat-colouring. This *contretemps* which we have just pointed out would not take place if a firm substance, and one perfectly volatile at a certain temperature, were invariably used as a means of fixing on the colour, as, for example, camphor, or borax, which contains no carbon at all. But the former substance is yet to be tried, and the latter could not always be conveniently used. Nevertheless, it follows from what we have already stated, that, of the substances which are adapted to fixing the painting upon the glass, the preference should be given to those whose combustion leaves the least carbon behind, and which at the same time preserve a certain ductility, as a security against cracking and splitting. Perhaps wax would answer very well with regard to these two particulars, for a portion of it volatilizes when it is exposed to heat, and it possesses moreover great ductility. For this purpose we have only to dissolve it in essential oil of turpentine.

It would be a waste of time to describe the various manipulations used here, which are purely artistical; and we would rather therefore confine ourselves to some few particular cases. Painting on glass is always done by copying oil-paintings, or original designs expressly prepared, which are called *cartoons*. The original design is traced by means of transparent paper, and this is used for transferring the drawing to the glass. For this purpose the piece of glass is laid upon the tracing, which has been first spread out upon a table. The transparency of the glass makes it easy to follow the outlines and shadows of the tracing; but if the glass is very much coloured and destitute of transparency, it becomes necessary to use a perforated pattern for finding out the drawing through the glass. This is a kind of tracing, the outlines of which are drawn through numerous contiguous punctures of the size of a needle's point. The paper which lies on the glass is then struck with a bag of powdered charcoal, and the outlines appear marked with sufficient distinctness. It is best to begin by drawing in Indian ink the object to be painted, when it is in our power to correct

and modify the sketch, just as we think proper, and then the painting* may be executed according to it with the greatest certainty. If corrections are made after the pigments have been laid on, a want of uniformity and completeness will always be observed in the work. Besides, correcting is then much more difficult. In other respects the same rules and precautions are applicable to glass-painting as to painting on canvas. The easel and the *maulstick* are used equally in both. The easel is constructed in a particular manner, which we shall describe hereafter. The pieces of glass that are placed upon it must be fastened with a soft adhesive wax prepared solely for this purpose. In order to take advantage of the transparency of the glass, the painter places his picture between himself and the light, and can at once judge of the effect of his work, as he proceeds.

A paint-brush or a goose-quill is used for drawing on glass with a pigment. A water-colour is best adapted to the goose-quill. Oil-colours, which are preferred for painting upon a flat surface, because they admit of being diffused more uniformly with the pencil, are not suited so well to the quill and do not adhere so well to the glass; nevertheless they are frequently used: A large quantity of sugar facilitates the drawing; still it is necessary to define the amount which should be mixed with the colour. Six grains of sugar to one drachm of colour produce a sufficiently strong adhesion, but for the quill at least seven grains of sugar must be mixed with the colour. A mixture of twelve grains would cause the colour to peel off. It is a very good precaution, when it is intended to paint with a quill, to wash the glass beforehand with essential oil of turpentine. Drawing in Indian ink is likewise more easily executed if this plan be adopted.

Should it devolve upon a glass-painter to paint a church window of large dimensions, he must begin by dividing it into more or fewer compartments which are surrounded by iron bars properly disposed and firmly united, so that all parts may be equally firm. He first determines the direction which is to be given to the iron bars and lead casing which are intended to unite the different parts of the picture. In doing this he must study to make these parts follow the outlines as much as possible, and to hide them in the shadows in such a way that they may not injure the effect of the picture. He ought not to be afraid of giving them a proper thickness, and increasing their number when necessary for the sake of greater firmness; this is of the greatest importance for the duration and preser-

vation of a work of art which is always exposed to the violence of the winds. It is a necessary condition which fetters the author of the original design himself in his composition. He must always take care that the execution of the painting will not require pieces of glass which are too large to admit of being durably fixed by means of iron bars and leading.

If the artists of the present day understand not only how to insure firmness to a painting on glass, but also at the same time how to satisfy the demands of the art as far as is necessary,—this, whatever may be said of it, is an improvement which we owe to the modern style of painting, and to which the manufactory at Sevres has greatly contributed. As for the rest, both these conditions may be satisfied at once without much difficulty. The presence of the iron bars and of the leading does not disturb the harmony of the painting nearly so much as would be supposed. Can this be a magical result of this kind of human creation? The human mind has the power of dismissing these obstructions, and the largest of them always appear like objects which are outside the picture. Now, whether the ancients sacrificed everything to solidity, or were deficient in mechanical skill, their church windows afford frequent instances in which the painting is far from harmonizing with the materials which support it. Thick iron bars are frequently carried across the figures or abruptly cut the masses in the furthest centre of light. Every one, therefore, will certainly coincide in our opinion, namely, that this is granting too much to the demand of solidity and too little to the effect of the painting. But did not a very simple principle of economy frequently predominate in this matter? This hypothesis seems at least reasonable, the construction of the *armure* being one of the most expensive parts of the construction of painted church windows. When we come to work the iron bars into complicated forms, this, as every one must see, can only be done at a great expense. It is a consideration of some importance why the ancients thought themselves obliged to restrict the claims of the art to limits marked out by economy.

After we have explained the various manipulations of the proper art of glass-painting, we must not omit to speak of a branch of industry which has something in common with the art with which we are at present engaged. We mean the manufacture of the *mousseline* glass, which consists in covering panes of ordinary window-glass with a coating of opaque white enamel, upon which a transparent sketch is drawn by *enlavage* which seems to be executed upon a faintly-polished ground.

To obtain this result, a fitch pencil must be used, whose form we have already described. This is dipped into thickened oil of lavender, and the surface of the glass is touched perpendicularly with it until the whole is covered with an uniform coating. As soon as this layer has acquired a proper consistency, a powder composed of one part of oxide of tin and three parts of a flux of the second class is sifted over it. The thickened essence retains a proper quantity of this enamel. This coating is then dried for six or eight hours, and after it has become sufficiently hard, the excess of enamel powder is removed by means of a badger's-brush-pencil.

Now, in order to draw upon a plate of glass like this lines which shall possess the polish and transparency of glass, we lay under the glass a pattern whose lines are sufficiently conspicuous even through the layer of powder. The pattern having been previously well secured, the artist removes by means of an etching-tool the colour from those places which are indicated by the drawing. This painting is now exposed to a proper degree of heat, that it may adhere or become burnt in. There is little in this operation that admits of the application of the proper art of glass-painting, the use of the wooden etching-tool alone being accidentally borrowed from this art. It is an exceedingly convenient tool for executing transparent drawings in imitation of embroidery; it is also much better adapted to *enterages* than the steel scraper. The method which is employed in producing white enamel is preferred on account of its succeeding in a very short time, but is better adapted to white enamel than to the other colours. Laying on by means of the fitch pencil insures greater uniformity, and enables us to obtain the requisite tone of colour with certainty.

The burning in of the painting.—The glass, after it has been painted, must be exposed to a temperature at which the pigments liquefy, and are thereby united to the glass. For this purpose the pieces of glass are arranged in a kind of box of fire-clay, called the *muffle*, which is placed in a furnace and there heated until the colours which have been laid on are liquefied.

Description of the furnace.—The furnace consists of four walls formed by bricks standing on their ends; these bricks enclose a space which is again subdivided into three parts. The upper compartment contains the muffle, which is open in front for the purpose of putting the glass in and taking it out. This aperture must be walled up, after the muffle has

been filled. The intermediate space contains the fire-place; the lower space contains the ash-pit. A cast-iron grate separates the fire-pot from the ash-pit; it is composed of single cast bars, in order that it may be more easily repaired. These bars are merely laid by the side of one another. Two or three arches span the fire-pot transversely, and are placed at equal distances from each other; they serve for the support of the muffle. An arch of burnt clay is perforated with several holes to allow the escape of the flame and the products of combustion. The muffle has a wide aperture in front for the purpose of putting in and taking out the glass, and another one of a small size under the arch for the escape of the gases which are evolved in the interior of the muffle. The door which closes the large aperture is usually provided with a sort of pipe in the middle, through which the experimental pieces of glass or the pyrometer are introduced into the muffle. By means of the latter we are enabled to observe the temperature. It is better, however, to have two apertures of the same kind, as we shall presently see on a closer examination.

Management of the painted pieces of glass in the muffle.—As the colours which have been laid on are to be melted, the plates of glass should not be placed in immediate contact with one another, or they would necessarily bake into one mass. They are therefore laid apart from one another by means of fire-proof earthenware shelves, (in France, by means of slabs of lava from Auvergne,) or plates of cast iron, which are ranged horizontally in parallel layers, so that a small space is always left between them. These shelves are kept apart by the insertion of small parallelopipeds of baked clay in the four corners. The shelves are also laid upon cross-bars of iron, of which two are used for every shelf, and are inserted at both ends of the muffle into notched bars; the former method, however, is preferred. Before the glass is put into the muffle, the shelves must be covered with a stratum of Spanish chalk mixed up with water, so that the glass, if it should happen to become soft when heated, may not adhere to the surface of the shelves. This coating of the shelves must be carefully dried, and then the pieces of glass must be laid side by side, but without touching one another; moreover, a clear space must be left at each corner of the shelves for the little supports which we have already mentioned. After the muffle has been filled, the aperture is hermetically sealed by being plastered over with clay which is proof against fire, and the front of the furnace is walled up with bricks. Thus shut up, the glass

may be heated without the colours being exposed either to the action of the flames or the vapours which arise from the fire-pot.

According to Dr. M. A. Gessert, to whom we are indebted for an excellent history of glass-painting, the introduction of the painted pieces of glass into the muffle is effected in the following way in Germany:—Well-calced lime is first of all slaked with water, and when it has crumbled to powder, is properly dried over the fire. The bottom of the muffle, to the thickness of an inch, is covered with this powder, as it falls through a coarse hair sieve; this substratum is carefully levelled, otherwise the pieces of glass might become distorted in the firing; these pieces of glass are then laid side by side, but in such a manner that they may not be in contact either with one another or with the sides of the muffle. A thin layer of lime is then sifted over them, other painted pieces of glass are disposed in a second series, and the process is continued, until we reach the centre of the muffle, at least the aperture for drawing out the tests, which consist of strips of glass from 6 to 7 inches in length and 1 inch in breadth, painted over with patterns of the colours which are to be burnt in. These, like the painted pieces of glass, are laid upon a stratum of lime, and sprinkled over with a coating of the same, but are so arranged that one end of them reaches to the centre of the muffle, while the other projects half an inch out of the test aperture, to admit of their being taken hold of and drawn out by the pincers. The artist then continues introducing the other pieces of glass, and strewing lime, until all have been arranged in their places in the manner above described, or the muffle is full. If only *one* has to undergo the burning in, the muffle is filled with ordinary pieces of glass instead of painted glass, and the only piece which is to be fused is introduced into one of the interior layers of the muffle. The latter is then covered up.

The furnace must be heated with wood, inasmuch as no other kind of fuel will answer the purpose, at least for the species of furnace of which we are now speaking, because the heating of the muffle is effected less by radiation from the fire-pot than by contact with the flames. Consequently that kind of wood should be selected which gives a long and bright flame, *e.g.* the wood of the aspen, birch, or poplar, which must previously be seasoned as thoroughly as possible. The fire must be made to burn up slowly, in order that the muffle may acquire the same degree of temperature in all

its parts. The ignited matter must therefore have time to propagate itself. Were we to proceed otherwise, the glass which lay next to the sides of the muffle would have already endured a degree of heat which would not only affect the pigments but would even bring the glass itself into a state of fusion, whilst the plates of glass which were situated in the centre of the muffle had only obtained the proper degree of temperature. The better to escape so unpleasant an occurrence, we must proceed in the following manner :

The fire must be constantly kept at a moderate temperature, until the muffle has attained a lively red heat, when the temperature must be lowered. The heat penetrates into the interior, and the muffle at last becomes of a dull red heat ; the fire is now stirred, and as soon as the muffle is again at a lively red heat, is lowered a second time. This is continued until the centre of the muffle is at the requisite temperature. According to this method it can never happen that the exterior of the muffle has already attained a high temperature before the interior is properly heated.

The temperature which it is intended to arrive at is generally a moderate cherry-red heat ; this is determined by looking into the various apertures of the muffle. But these observations are very liable to error, because we are not always in the same condition with regard to light. Suppose, for instance, that the room in which the furnace stands is very well lighted, then the red-hot muffle is not nearly of so bright a colour. In a more subdued light, the red appears much more intense ; so that one day's experience is frequently fallacious. It is therefore necessary to hang curtains before the windows, in order to obtain a tolerably uniform light for this examination.

The temperature is also determined by painted pieces of glass for testing, which are laid in the apertures of the muffle ; but such tests as these are not conclusive, inasmuch as they only indicate a local temperature. An experiment made in one part of the muffle affords no clue towards determining the state of the other parts. But if after all the artist should be disposed to use this test, he must endeavour to keep always below the requisite temperature, and to lower the fire before the test-glass has actually arrived at the proper degree of fusion ; for he may be sure that the temperature will increase towards the centre. Carmine is generally employed in experiments of this kind. The changes of colour which it undergoes in mass, when it is raised to a higher temperature, render it peculiarly adapted to this purpose. When not much heated it has a dirty

violet colour, it then passes over into pure carmine; and when at length it is heated too much, it appears yellow in reflected light, and violet in refracted light, that is to say, upon an opaque body, *e. g.* a piece of porcelain, it will appear yellow; upon a piece of glass, on the contrary, in transmitted light, it will appear violet.

Finally, the temperature may be determined by means of particular instruments contrived on purpose to measure the heat of the furnace. Among these are the *pyrometers* of Wedgewood and Breguiat. The former is constructed on the principle that clay contracts in proportion to the heat to which it is exposed. It consists of a plate of copper, on which two or three rulers, likewise of copper, are fixed. Between these is inserted a cylinder of clay baked in the fire, which has been exposed to the degree of heat which is to be determined. The more it diminished in bulk, the greater was the degree of heat which was applied. The instrument is divided into 240 parts. The zero answers to $580^{\circ} 55$ Centigrade; every degree is equal to $72 \cdot 22$ Centigrade. This pyrometer is therefore adapted to the measurement of very high temperatures, but does not answer well in the case before us, in which the other is preferable. This latter is constructed on the principle of the expansibility of the metals by heat, and consists of an apparatus of baked clay, along which a groove runs longitudinally, but stops short of one of the ends. A bar of metal and another of baked clay lie in this groove in such a way that their ends touch one another. The other end is furnished with a dial-plate, in the centre of which a finger moves, one end of which is in contact with the earthenware bar in the groove.

That part of the instrument which contains the bar of metal is introduced into the muffle in such a way that the bar shall be completely in the muffle. As it expands by the heat, it must necessarily, since it lies at the end of the groove, push forward the earthenware bar; the latter again communicates the impulse to the finger, which then indicates upon the dial-plate the expansion which has taken place. The metallic bar must be made of a metal whose point of fusion is far beyond the temperature necessary for burning in the painting; it must not even become too soft at this degree of heat. Iron and silver may be employed for this purpose, but silver is generally preferred, because it becomes less oxidized. If a metal still more difficult of fusion were required, a bar of platinum might be used.

In order that we may use this instrument effectually, the

following conditions must be complied with: the door of the muffle must be furnished with two apertures, one of which must be made in the lower part, and the other in the middle, or rather about the upper third of its height. A pyrometer is prepared for each aperture. When the lower one indicates a dull red heat, the fire is not allowed to increase, but is stirred in proportion as the heat has been reduced below that temperature. The artist proceeds generally according to the directions above given, until the upper pyrometer indicates a proper temperature.

In beginning to light the fire, it is important to cause a feeble current of air to pass through the muffle, in order to allow the gases, which are formed in the latter, by the combination of the substances which are used for fixing the painting with those which come out of the fire-pot, and penetrate through the sides of the muffle, to escape with rapidity. For this purpose one of the apertures in front, as well as that of the upper part, is left half-open. Upon the latter is also placed a stove chimney, a few decimetres in length, which when heated draws the air out of the interior of the muffle, and accelerates its upward motion. It is only when the muffle is being first heated that the most injurious of the external gases penetrate in larger quantities. After it has arrived at a red heat, they become more completely dissipated on the exterior. These gases always exercise a pernicious influence upon the painting, which it is necessary to guard against.

The creating the current of air of which we have just been speaking is not less useful as a means of obviating an unpleasant occurrence, which, without this precaution, frequently takes place, viz. the *cracking* of the painting. This may be explained as follows: When the muffle is being first heated, a large quantity of smoke often penetrates through the hole at the top. The glass is still cold, whilst the sides of the muffle are hot; consequently the aqueous vapour of the smoke condenses in small drops upon its surface. As soon as the glass begins to grow hot, the water which lies upon it begins to boil before it is converted into steam, and at last affects the painting with which it is in contact. The consequence of this is, that a peculiar kind of cracking takes place, similar to that which varnish undergoes when it is laid on an oil-painting just finished. The possibility of this accident is diminished by creating a draught of air at the commencement of the heating; but this draught should not be so strong as to chill, and consequently to crack, the objects with which it comes in contact. If this

be avoided, it seems to be attended with no other prejudicial results.

There is also another source of moisture, viz. in the clay with which the door of the muffle is plastered over. It is customary, therefore, to heat for a short time the muffle, with its contents, before plastering on the clay, and to close the furnace. The muffle being already hot at the time the clay is laid on, its contents are not so likely to condense the vapour.

That kind of glass-painting which is executed with coloured fused pigments is not finished after the first firing. The fusion of the colours gives in general too feeble a tone of colour. The pigments of the first class especially lose some of the intensity of their colour when they are exposed to too high a temperature. It becomes necessary after the first firing to give expression to those parts which are deficient in this particular, and generally to impart the requisite harmony to the whole. It is even sometimes useful to re-touch the work after the second burning in, and in this case a third burning in becomes necessary; but the painting is not capable of bearing more than this, for a large portion of the pigments would be considerably damaged and even entirely destroyed by the repeated action of heat. When a painting is to be burnt in a second time, and it becomes necessary to restore harmony to the various parts of which it consists, the artist generally lays them together in the position which they are afterwards intended to occupy, in order that he may be enabled to judge of their combined effect. For this purpose he fixes them in their respective places upon the glass plate of the easel, or upon a plate of glass of a proper size, which is placed in a frame.

There are two ways of holding the pieces of glass together. They may be fastened upon the glass plate with wax, which is spread out between the fingers and rolled upon a flat surface. The wax takes the place of the leading, and fills up all interstices. The pieces of glass may also be encased in lead. Fastening with wax has the advantage of being materially cheaper than leading, only it is deficient in solidity. When it is warm, the wax becomes so soft that the pieces do not hold together well, and numerous accidents are the result. A work which has occupied much time may be ruined in a single moment. It is also difficult to free the glass entirely from the wax which adheres to it without a considerable loss of time, and if any wax remains behind it is injurious to the painting. Besides, the idea that leading is more expensive is merely

illusory, when it is the painter himself who fastens the pieces with wax; for the cost of the leading is more than compensated for by the value of his time, because the former is done by a glazier, who only solders together the ends of the strips of lead. Fastening with wax is only practised at Sevres; at Munich leading is preferred.

OF ENGRAVING UPON GLASS WITH HYDROFLUORIC ACID.

This style of decoration, which has nothing in common with the proper art of glass-painting, is nevertheless frequently and advantageously employed as an assistant to this art. It is generally used for *overlaid* glass, as it is called (white glass, upon which a coating of coloured glass is fixed in the blowing). It consists of a kind of white drawing upon a coloured ground, and it is obtained by removing the coating of coloured glass in all those places where it is intended to lay bare the white stratum, according to the form of the drawing. The process of engraving is as follows: The glass is first covered with a coating of oily copal varnish, or, what is better, with merely linseed oil which has been boiled with litharge, in order to preserve from the action of the acid the parts which are not to be etched. This layer is dried in the drying-oven, and the varnish is then removed by means of a graver or needle, and a scraping instrument, from those parts where the glass is to be acted upon by the acid. As soon as this operation is finished, the plate of glass is laid horizontally upon a table, and a raised border of wax is carried round the edge which is capable of containing the acid, which is then poured up in the glass. The acid is allowed to remain upon the glass as long as is necessary to destroy the coloured stratum wherever it is exposed. After this, the piece of glass is washed and freed from the border of wax and the wax ground. The engraving is clean and fine in proportion to the thinness of the coating of glass, and the diluted state of the acid. If the acid is very much concentrated, its action extends over the etching ground, and the lines seem undermined. This kind of drawing is frequently employed for exhibiting silver embroideries upon coloured dresses. It is white at first, but may be coloured yellow, so as thus to imitate gold ornaments.

Glass may be etched by means of hydrofluoric acid, because the latter has the property of dissolving silica. But on account of the exceedingly pernicious effect of this acid upon the health of those who employ it, it has been hitherto almost impossible to use it. In order, therefore, to apply the art of etching on

glass to the arts and sciences, it became necessary to find out another means of etching, perfectly harmless, and a suitable etching ground. Dr. Bromeis, of Hanau, a clever young chemist, and after him the celebrated professor, Dr. Böttger, of Frankfort-on-the-Maine, each however by himself, and without being acquainted with the researches of the other, have now discovered such a method of etching, and by means of it have etched plates of glass of any thickness, and have prepared them for giving impressions in the presses which have been hitherto generally employed.

Professor Böttger gave a full account of this invention, which is called *hyalography* by the inventors, in a lecture delivered at a meeting of the *Physical Society* of Frankfort. At the same time he pointed out the advantages which were associated with this discovery, of which we shall only particularize the following:

1. The substance used for etching is *perfectly harmless*, and no vapours or gases are evolved, which, as is the case in copper-plate engraving, are in the habit of producing an injurious effect even upon the plate; moreover, it does not lose its strength, the same quantity can be used for etching several hundreds of lines in glass.

2. Glass admits of an exceedingly delicate treatment, and the lines are more perfectly developed than in engravings on steel or copper.

3. All kinds of porcelain and flint-glass may be very easily supplied with colouring and glittering ornaments, by rubbing in the drawings that are etched upon them with vitreous porcelain colour, which is not difficult of fusion, and then burning it in the muffle.

The inventors intend to make known their method, which, independently of *hyalotypy*, promises to be of great interest, for a very moderate remuneration, as soon as at least fifty persons in the district of the Zollverein will combine to purchase it.

The easel proper for glass-painting.—The easel consists of an oblong wooden frame, whose greatest dimension is its height. Its interior edge is furnished with grooves for the reception of a plate of glass. This frame is placed in a larger frame, and may be raised or lowered in grooves at pleasure. We have an exact representation of it in the old sash-windows. The exterior frame has a series of holes in the direction of its height, on both sides, and the interior frame can thus be supported at any given height by means of pegs which are inserted into

these holes on either side. This apparatus is placed obliquely on a table, and supported in this position by two props, at the back, which are joined to the upper part of the large frame by means of two hinges. These two pieces are joined together by a cross-bar, and held at a proper distance from the frame by means of moveable iron hooks; a contrivance precisely similar to what we find in step-ladders, for, like them, when it is not wanted to be used, it can be shut up, so as to occupy less room.

Mill for grinding the pigments.—The mill is a circular vessel of porcelain, which receives the runner and the substances to be ground. The bottom of it, towards the centre, rises in the form of a conical or rounded projection, which forms with the lower part of the side a wide groove, in which the runner moves. The runner consists of a thick crown of porcelain, formed out of the segment of a cylinder. It is placed perpendicularly in the vessel, projecting above it. Its lower edge is situated in the groove. As it is supported by the bottom of the vessel, it is capable of revolving on its axis in a horizontal direction. The levigation of the pigments is therefore effected by the rubbing of the lower edge of the runner upon the surface of the groove. This groove is intended to retain the runner in its position, and to cause the substances which are to be ground to collect at the points where the grinding takes place. The upper edge of the runner is level. It has two holes situated opposite to one another, and bored perpendicularly from the surface: they serve to fasten on the piece which is destined to communicate motion to the runner.

A tin plate, of the width of the runner, closes the opening at the top. It has two pegs, which are inserted into the above-mentioned holes. By this contrivance the runner is made to follow every motion which is communicated to the plate.

There are two ways of causing the motive power to act by the help of the plate of metal. We may act upon a point in the circumference by means of a revolving handle, which is let into a wooden plate that serves as a cover. This is the simplest method: but as in this case the runner moves at liberty in its receptacle, as soon as it meets with any check in its circular motion it suddenly quits its path, and the moving it then becomes very troublesome. This might be entirely obviated by means of a pin passing through the centre of the runner and of the outer vessel; but it is better to produce motion by means of a crooked handle, which is made to work in the following manner: The upper surface of the metallic plate

has in its centre a circular iron bar, well secured. This bar or spindle serves as an axis, and turns in a hole which is bored in a horizontal cross-piece, or rather in the centre of the lid of a box which covers the runner. The handle is fastened on just where the axis projects out of the box. By this means the centre of the runner is always retained in the same place. It assists the action of the handle, which thus distributes the impulse it receives to all parts at the same time; consequently the runner cannot suffer any concussion, as in the foregoing case.

When the pigments are being ground, it is often advisable to increase the weight of the runner at the commencement of the operation. This is done by placing upon the tin plate another plate of lead of the same diameter, whose weight may be determined at pleasure. It is moveable, and can be easily laid on the plate, and at the same time as easily removed, for which purpose it is merely necessary to take the handle off.

The drying-oven.—The drying-oven is constructed of baked bricks, and at the bottom of it is a cast-iron plate. This cast-iron plate lies over the fire, from which the necessary temperature is conveyed to the interior of the oven. The interior is provided with wire sieves, fixed in frames lying horizontally at short distances one above the other, which admit of a free circulation of air. In front of the oven there is a door, which is closed as soon as the pieces to be dried have been laid in their places. The heating apparatus is similar to that of a common oven which is heated with charcoal or coal.

Furnace.—The furnace consists of a wall of baked bricks,—a fire-pot, the interior of which is lined with fire-bricks, as well as with a coating of clay which is proof against fire,—the grating,—the ash-pit,—a pipe through which the air is conveyed from a pair of bellows into the ash-pit; and grating perforated with several holes, in order to distribute the wind of the bellows uniformly throughout the interior. A good smith's bellows should be used for this furnace.

This kind of furnace is preferred to the common draught-furnace for the preparation of the pigments, because it is capable of producing a very high temperature, and by that means shortening the operation.

Wax for fastening the plates of glass upon the easel.—This wax is similar to modelling-wax, and consists of bees'-wax, 4 parts,—Burgundy-pitch, 1 part.

It owes its ductility to the Burgundy-pitch, and its adhesive property principally to the greasy matter which the bees'-wax

of commerce almost always contains. If this is found to be wanting, the deficiency should be supplied by mixing with it tallow in small quantities.

CHAPTER IV.

THE WORK OF THE GLAZIER.

THE work of the glazier consists—1. in cutting out the various pieces of glass which are to be painted, and in giving them exactly the form which the drawing requires;—2. in encasing the glass in lead when the painting is finished, and forming it into the panels of which the whole picture is composed;—3. lastly, in arranging it permanently in the *arming*.

In the two first operations the glazier is guided by a cartoon prepared expressly for this purpose. Upon this the outlines of the pieces of glass are indicated by a mere line, which at the same time determines the arrangement of the strips of lead. The irons by which the glass is fixed in the window are likewise drawn here in their natural dimensions.

Of the cutting the glass.—The cartoon having been placed on a table, the glazier lays upon the drawing a plate of glass, whose colour has been determined to a nicety by the painter. He draws the outline of the piece with a brush containing white paint, and then cuts it with the diamond, after which he brings it to the exact form by means of the *riesel-iron*. Among other things he takes care to leave a space between each piece of glass, which is determined by the thickness of the interior of the strip of lead by whose edges the pieces of glass are afterwards to be united. The colour with which the glazier draws the outline of the pieces which are to be cut out is composed merely of Spanish white and weak gum-water; the paint-brush which he employs for this purpose consists of long, flexible hairs attached to a thin cylindrical stick. The painter on porcelain also uses this pencil, and it has the advantage of yielding a line of uniform width.

Although the diamond and its use are well known, we shall, however, mention a few interesting particulars in relation to the properties of this instrument. The diamond which cuts with its natural edge is preferable to that which comes from the hands of the lapidary; for such a diamond only cuts by means of an angle artificially produced. The latter may be very

easily seen, when looked at with a magnifying-glass, to possess level sides, and to form a rectilinear edge where these planes intersect. That of the natural diamond is not perfectly rectilinear, but always convex; and this is just the form which is best adapted to cutting glass. When the diamond acts upon the glass by means of one of its edges, it either cuts or furrows it. But in this there is an essential difference, for a piece of glass which has been merely furrowed can never be so well divided. The diamond leaves a scarcely visible trace upon well-cut glass; on furrowed glass, on the contrary, a very distinctly fringed groove may be observed. When the diamond is cutting well, a low, monotonous sound may be heard; if it is furrowing, the sound which it produces is very perceptible to the ear and even to the hand of the glazier. When a line has been drawn with the diamond, and the endeavour which is made to break off the piece of glass is fruitless, the attempt must not be obstinately continued, for it is only necessary to strike gently with the handle of the diamond or some other hard body upon the side opposite to the cut, in order to cause it to begin to separate; only a little more trouble is then required to carry on the separation along its whole length. In this way we avoid breaking the glass. When it is necessary to cut a piece of glass of such a form that it would be difficult to cut it with the diamond, and the attempt would probably fail, recourse may be had to the action of fire.

After the outline of the piece which is to be cut off has been drawn, a little incision is made with the diamond in any part of the line, the glass is then heated with a hot coal at those points through which the separation is to be continued, the heating beginning at the point where the diamond has commenced the separation. If the coal is carried in this way slowly over the glass, in proportion as the separation takes place, the whole piece is at last disengaged. The glazier would do well, however, to draw the piece rather larger than it ought properly to be, for fear that any deviations which might take place as the crack is being continued should spoil the whole piece. The *riesel-iron* is used as a finishing tool to give the requisite form to the glass.

To prevent the necessity of blowing incessantly upon the coal, in order to keep it burning and sufficiently hot, pieces of white wood saturated with subacetate of lead are used, which possess the property of continuing to burn without further assistance, as soon as it has once been ignited at one of its ends. These pieces of wood are generally cut from the willow

or poplar, and are then steeped for several days in a solution of the above-mentioned salt, after which they are dried. They are very convenient for hot coals.

The glazier must be supplied with rectilinear and also with curvilinear rulers of various kinds, for cutting the glass. Suppose he has to cut a piece of glass of complicated form—he removes, first of all, from the plate of glass by a rectilinear cut, the glass which lies outside the proper outline, and then, by several cuts in succession, he penetrates into the corners, so that at last it is only necessary to use the *riesel-iron*.

The riesel-iron.—This tool consists of a blade of soft steel $1\frac{1}{2}$ line* in thickness, and about 5 inches 5 lines in length. At each end is a shallow notch in the direction of its thickness; and by means of these notches a number of small fragments are clipped off the glass one after another, so that those parts which are outside the outline are removed with tolerable rapidity. The glass to be operated upon is held in one hand, and the *riesel-iron* in the other; the edge of the glass is then inserted without any difficulty into a notch of the *riesel-iron*, and by gentle pressure downwards and upwards, the part which lies in the notch is broken off. This action is rapidly and continually repeated, but the use of this instrument requires some skill. The *riesel-iron* must be made of soft steel, and thus possess sufficient flexibility to hold fast the corner of the glass, and at the same time must be hard enough to last a long time for this continuous work. Iron would be too soft.

A *riesel-iron* of a somewhat different construction is also used, which is suited to glass of any strength, and which can be easily repaired. It consists of two perfectly level rulers, 5 inches 5 lines in length, at one end of each of which there is a rectangular projection a little more than a line in length. These rulers fit one upon the other in such a way that that end of the one which is without a projection is received by the angle of the other, so as to form the notch of the *riesel-iron*. The two rulers slide upon one another, and are joined together by a band, by the binding screw of which they can be fixed in any position. By means of this apparatus, the proper width may be given to the notch, and the instrument may be easily repaired by being taken to pieces.

Of the leading.—After the various parts of a painting on glass have been burnt in, the parts themselves must be united,

* The line is $\frac{1}{12}$ of an inch, according to French measure.

so as to form a whole. This operation is performed by means of strips of lead in the following manner :

These strips of lead consist of two narrow ribbons joined together lengthwise, by one narrow slip of the same metal running along the centre of both. The arrangement of these three pieces produces a groove in each side of the strip of lead, for the purpose of receiving the edges of the two pieces of glass, which border on one another, and which are thus separated by the middle slip, and covered by the overlapping parts of the leading. The length of the strips of lead is determined at pleasure, and the breadth should be from two to six *lines*, so that the overlapping part may be from two to four *lines* in breadth. We shall afterwards explain how the strips of lead receive their proper form.

The cartoon, according to which the pieces of glass have been cut out, is also used for putting them together and leading them. The glazier begins as nearly as possible in the centre of any of the panels which are to be made up. As soon as the first piece which is to be fixed has been laid in its proper place, it is fastened in several places by pegs which are driven into the table. These pegs or nails without heads accomplish this purpose by the help of small pieces of milled lead, which are laid between the pegs and the glass. One of the sides of the piece of glass is then enclosed in a piece of lead. After this piece has followed the whole outline of the piece of glass, during which pressure has been applied by means of the *lead-jack*, the superfluous breadth is cut off with the lead-knife. A second piece of glass is then fitted on, which, like the first, is fixed with pegs, until a strip of lead has been fastened on. The edges of the lead are pressed down with the *lead-jack*, and the operation is continued until the panel is finished.

The glazier then proceeds to the soldering, which consists in applying the solder to the joinings, thus uniting the various pieces of lead and imparting a greater firmness to the net which they form.

The solder is an alloy of lead and tin, less flexible than the pieces of lead themselves,—consequently it imparts to them a greater power of resistance. In this alloy the tin and the lead are united in equal quantities. Before the solder is used, it must be previously prepared in such a way that it may be conveniently applied. Lead is melted in an iron basin or pot, and as soon as it has become liquid, an equal quantity of tin is added. This done, it is kept at a moderate temperature, and

a small quantity of resin or grease is thrown into it, which de-oxidizes the metal, and thus restores it to a perfectly liquid state. The oxide and the foreign bodies which float upon the surface are then removed, and the metal is poured out. It is best to cast it in thin ribbon, which on account of its form and its pliability can be much more easily handled. This ribbon may be obtained by pouring a small quantity of solder upon a grooved plate, and inclining the latter a little in the act of pouring. The inclination of this mould must be such that the ribbons or strips which are thus obtained shall be sufficiently pliable without being too thin. As soon as the glazier has provided himself with a sufficient quantity of solder, he sets to work. The solder is applied by means of the soldering-iron: this implement consists of a piece of copper in the form of a cone, the base of which is prolonged, and serves as a handle: the latter is held in the hand by means of two concave and moveable pieces of wood which completely surround the hand in their junction. The soldering-iron might also be made of iron, and then it would probably be more durable; but iron does not seem so well adapted to receive the solder as copper. The soldering-iron must be previously tinned at its point. For this purpose, it is necessary to have a tin plate rather concave in form. After the soldering-iron has been heated in a proper furnace, it is rubbed over a piece of sal-ammoniac, in order to clean it, and then over the before-mentioned tin plate, upon which a little resin has been sprinkled for the purpose of de-oxidizing the tin. The soldering-iron then receives a portion of tin from the tin plate, and becomes thereby tinned. It is advisable to clean the tinned end of it, whenever it is taken from the fire, by passing it over the tin plate, the metal of which must be renewed as soon as it becomes necessary.

The soldering-iron having been properly heated and tinned, is brought near to the lead, upon which a small quantity of resin has been previously sprinkled. In this position, the solder, which is applied with the other hand, is melted: it is then diffused uniformly and regularly, by the point of the soldering-iron being made to pass over the whole surface of the lead. The soldering-iron must be heated to the proper temperature: if it is too hot, it will melt the lead; if it is too cold, it gives the soldering a wrinkled appearance, which proceeds from the imperfect fusion of the alloy. The lead is soldered on one or both sides, according to the degree of strength which is to be given to the leading. As soon as the soldering is finished, the lead is cleansed from the resin that remains by being rubbed

with a piece of linen which has been dipped in oil of turpentine.

The furnace for heating the soldering-iron is nothing more than a circular tin box, with neither grate nor draught. This box is generally placed on three feet, sufficiently high to allow of its being conveniently used. The coals are made to burn up merely by a pair of hand-bellows.

Preparation of the glazier's lead.—The bars of lead are cast in a mould, and when in a rough state bear some resemblance in shape to the strips we have already described, for the production of which these bars are used. The mould is a sort of frame consisting of two parts, each of which is from 1 inch 6 lines to 1 inch 10 lines in breadth, from 5 to 7 lines in thickness, and from 1 foot to 1 foot 6 inches in length. These two pieces have each three longitudinal grooves, which, when they are joined with those of the opposite side, form the cavities in which the bars are cast. The parts of the mould are united at one end by a hinge which admits of the grooves of the frame being shut and opened at pleasure. At the other end of one of these parts is a bifurcated handle which moves on a hinge, and which is capable of clasping the opposite piece with its fork and holding it fast. The grooves of the frame are terminated by a transverse groove near the handle, into which the metal is poured. The frame being shut, is held perpendicularly by the handle with one hand, while the melted lead is poured in with the other. As soon as the lead has solidified, it is taken out of the frame, in order to make room for other castings.

After the casting is finished, the bars are smoothed, that they may be subjected to the milling machine, whereby they are converted into what is called 'glazier's lead.'

The milling machine.—The milling machine consists, first, of two vertical cheeks, which are parallel to one another, and are held together by strong cross-pieces, by means of screws and burrs. Each cheek is furnished with two wide holes between the cross-pieces, in which there are as many revolving cylinders, which we shall presently describe more fully. The corresponding holes in each cheek are at the same height from the bottom of the machine. At the bottom of each of the cheeks also there are two horizontal projections chamfered off, and furnished with holes to receive the iron bolts with which they are fastened to a bench. Two iron cylinders pass horizontally through the intermediate space between the cheeks, and their ends are let into the above-mentioned corresponding

holes at each side. The upper cylinder projects beyond the hinder cheek, and at the end of it is a tooth-wheel of 12 teeth, which is held in its place by a burr. The other end of the cylinder only extends to the outer surface of the cheek. The lower cylinder projects beyond the cheeks at both ends. At one end there is a tooth-wheel similar to the one we have already mentioned, into which it fits; the other end is squared to receive a Level. On each of the cylinders, at an equal distance from either of the cheeks, there is a wheel, or disk, which is capable of being disengaged from or fastened to the cylinder. These two disks are thus situated opposite to one another, without, however, coming in contact. The bar of lead which is to be drawn out by the revolving motion of the disks in opposite directions, when the cylinders are set in motion by means of the handle, must pass between these two disks. Their thickness determines the breadth of the groove, and the distance at which they are apart the thickness of the interior strip. On the circumference of these disks there are a few lines engraved, like the scratches of a file, and these are for the purpose of holding the lead more securely.

To each of the cheeks between the cylinders there is attached a heavy piece, of complicated form, which is called the *die*. The die, which is let into a mortised hole in its corresponding cheek, presents an angular surface on its opposite side, which is bounded at the top and the bottom by a rectilinear part called the *nageleinsatz*.

The two planes of the angular surface bear the name of *engorgeures* in French, the broader one being the *engorgeure d'entrée*, the other the *engorgeure de sortie*. At the top and at the bottom of each die there is a semicircular groove corresponding to the adjacent cylinder. It is now evident that the dies, in their mutual relations to one another, in conjunction with the disks, complete the mill which is to give the proper shape to the lead. They serve to form the outer surfaces and the sides of the lead, just as the disks form the core and the grooves. In order to draw the lead, the end of the bar is placed between the two disks in the intermediate space between the dies; the handle being now turned, the bar must pass through the rolling-press, and receive the form and dimensions of the latter. In this operation the lead is considerably lengthened: a bar one foot long will give a strip of lead of more than four feet in length. It is impossible to obtain milled lead of various dimensions without having several pairs of wheels and dies of proper sizes; consequently, if the disks

are fixed to the cylinders, it is necessary to have just as many cylinders as disks.

The bench of the machine consists of a simple piece of wood, the ends of which are supported by three legs fixed in the ground.

Before the lead is placed in the machine, it must be smoothed and then *condensed*. The latter operation is performed in the following manner: One end of a bar of lead is bent into the form of a right angle, which is placed under the foot, while the other end is wound upon a piece of wood, by which means the lead is forcibly drawn out: it is thus considerably lengthened, and becomes more rigid. When it is to be used, the lead-jack is passed between the overlapping edges to separate them from one another, so that the glass may be more easily pressed into the groove.

Of the arming.—The chief object of the *arming* is to impart sufficient firmness and power of resisting external violence to church windows. The net of lead which holds the pieces of glass together is by no means capable of doing so for any length of time, unless it is of very small dimensions or supported at certain distances by iron bars. But this iron-work contributes sometimes even to the decoration of the window: Gothic church windows afford an example of this, which consist of numerous panels containing forms of various kinds artistically disposed, so that the whole presents a very pleasing appearance. Here the *arming* pays its tribute to the art by affording the requisite strength to the window: it isolates the panels, and renders their agreeable outlines conspicuous, while at the same time by its complicated pattern it forms a drawing so much the more powerful and effective, as it appears black upon a transparent ground. In those windows, on the contrary, where the *arming* is evidently of no use to the painting, but is merely for the sake of rendering the glass secure, its presence cannot be otherwise than prejudicial to the effect; therefore, in that case, it must be our object to conceal it as much as possible in the shadows, unless we prefer presenting it to the eye as a piece of trellis-work, independent of the picture, just as is generally the case in church windows. The ancients did this very frequently, from a principle of economy.

There are several other methods of constructing the iron *armings*; sometimes, for example, as in the case of Gothic windows, simple iron bars, which have been bent into the form of the outline of the panels, are used, and the latter are fastened to the bars by means of pins disposed at equal dis-

tauces throughout the whole extent of the former; sometimes there are iron bars which in certain modern church windows receive the panels in grooves in which they are fixed by nails running transversely through them. Sometimes there are merely thin iron bars disposed at the back of the painting, which, by means of bands of the same metal laid on the lead on one side, carried round it and twisted together on the other, render the leading compact.

Armings which are furnished with grooves are difficult of construction: the bars are composed of two plates, which are connected longitudinally at right angles, one in the centre of the other, by means of clenched rivets; or they may be made of a single strip of tin bent at right angles, and then bent back again, so as to form two right angles, which constitute the groove. This kind of *arming* is exceedingly expensive, and will always increase the cost of those church windows to which it is applied. The Gothic *arming*, although simpler, is nevertheless always expensive, on account of the great strength of the iron and the splints which belong to this kind of *arming*. The *arming* which is constructed with thin bars and with ribbons of lead is much more easily prepared, but is less durable, and presents no pleasing appearance.

After the glazier has arranged the panels in the *arming* with splints, nails, or ribbons of lead, he cements all the places through which the rain is capable of penetrating, and thus finishes his work.

CHAPTER V.

ON THE INGREDIENTS FOR COLOURED GLASSES.

THE preparation of the glass which is coloured in mass is, strictly speaking, no part of glass *painting*, but belongs properly to the art of *making* glass. Since, however, such kinds of glass are frequently used by glass-painters, we shall here briefly state the ingredients proper for the various kinds of coloured glass.

If we mix with glass, at the time of its manufacture, certain metallic compounds, we impart various colours to it, the shades of which we are capable of varying to any extent by following the general rule, viz. that according as it is required to increase or diminish the intensity of the colour, a small quantity of the colouring metallic oxide must be either added to or taken from the mixture. The colour thus imparted is not superficial, as

in the case of porcelain and enamel painting, but is diffused throughout the whole mass, the colouring matter having become a real constituent part of it. In other respects, the same substances are applied to this purpose as are used for the colouring of the pigments in general.

Of the purple glass.—Gold is employed to give a purple colour to glass, similar to that of ruby, for such glass is the most perfect imitation of the ruby in colour, and resembles it almost in brilliancy and liveliness. There is no other substance which is capable of imparting a red of so beautiful a tone to the pot-metal; but extremely delicate manipulation is required in the management of the gold, and a variety of precautionary measures are necessary to insure success. The precipitate of Cassius is the preparation of gold which is most frequently employed for colouring glass purple. We have already described the methods of obtaining it, and we shall now state the reason why it is generally preferred to the rest.

The precipitate of Cassius is one of those combinations containing gold which possesses the greatest stability. It resists a high temperature, and if the reduction of the gold, as we believe it to be, takes place after it has united with the glass, this will only happen at the moment when it can be held by the whole mass in the state of division in which it exists when united with the tin. This combination is less disposed than any other preparation of gold to pass over into violet or blue. The purple of Cassius absolutely requires, in order to be used, to be levigated in a gelatinous state with pulverized glass, borax, or any other substance which is capable of entering into combination with glass, and this with a view to prevent a conglomeration of the particles of the gold. Its power of colouring is such, that one part of the purple of Cassius is capable of colouring 1000 parts of glass. In using this purple it is customary to mix with it the sixth part of its weight of the white oxide of antimony, in order to give the glass a faint tinge of yellow, which reduces the red that slightly approximates to violet to a lively purple. In other respects, all that we have said about the pigments coloured by means of the purple of Cassius applies just as well to the colouring of glass in the melting-pot.

Fulminating gold is also used for colouring glass purple. It is one of those combinations which are obtained by precipitation with ammonia from chloride of gold. Its property of exploding at a very low temperature renders it unsafe to use. In order to deprive it of this property, it is customary to mix

it with silica, lime, &c. The same result is obtained with a fixed alkali, the mixture being exposed to a gentle heat. It is also sufficient for the purpose to levigate the mixture with essential oil of turpentine. But the precautionary measures which we are under the necessity of adopting, in order to prevent an explosion, are at the same time indispensable to success in colouring, and that too on the same principle which guides us in the preparation of the purple of Cassius. I mean that the fulminating gold, while moist, must be mixed with a substance which will deprive it of its explosive property, and at the same time hold it in a state of the most minute division.

The purple colour of glass may also be produced by using chloride of gold, sulphuret of gold, and even from aurates, if the operator proceeds according to the method which prevails in the other preparations of gold.

Of the red glass.—The red glass receives its colour from copper, if not in the metallic state, at least at the degree of strongest oxidation. To make red glass, a mixture of sulphuret of copper and oxide of iron is added to the melted mass of glass; or, after a green has been first produced in the mass by means of oxide of copper, the metal is deoxidized by the mixture of a substance containing carbon, and the colour is thus made to pass over into red; this deoxidizing substance is usually bitartrate of potash. It has been found that any other combination which contains carbon would produce the same effect.

Carmine is obtained from copper only; a darker red, from a mixture of iron and copper, in which the former is to the latter as three to one. The quantity of iron is diminished, if it is intended that the tone of the colour shall approach nearer to that of carmine. The glass must be worked as soon as the proper red colour makes its appearance, otherwise it would speedily disappear.

The red which is obtained from copper is so intense that it is necessary to conduct the operation with the greatest care, in order that the glass may not lose its transparency, for it is often in danger of becoming perfectly opaque. Our object must therefore be, to find out a method by which this risk may be obviated. Now this method consists in overlaying the white glass with an extremely thin coating of red glass (*flashed glass*); it is only in this way that transparency can be combined with a beautiful colour.

The ancients only mixed crude tartar, soot, or other de-

oxidizing bodies, with the mass which had been coloured by copper, for the sake of obtaining the red. But it is best to use protoxide of tin, in order to obtain copper in the state of protoxide. The action of protoxide of tin is not so transient as that of the vegetable substances, whose action naturally terminates with their combustion, and in using which we are liable to a double disappointment; for if they are not sufficiently consumed, the glass will not be so clear, nor the colour so bright, and as soon as the colour has come out properly we must proceed to work up the glass as quickly as possible, because the colour is exceedingly liable to disappear. But all this is avoided by using protoxide of tin. According to Dr. Engelhardt's experiments, the red continued equally fine throughout the whole process, and he never found himself obliged to add deoxidizing bodies. He also met with oxide of tin in all the ancient kinds of glass which he examined, and this oxide was for the most part present in greater quantities than the protoxide of copper itself.

Now, since the colour imparted by protoxide of copper is too intense to admit of its being worked up alone, and the plate which has been coloured throughout would be opaque and appear dark brown, and since it would be necessary to blow it exceedingly thin, in order that the red may become transparent, we can only obtain manageable red plates of glass by flashing a white plate with a very thin coating of red glass. There is, moreover, this advantage in flashed glass, viz. that the red coating may be ground off in different places; thus we obtain white sketches, or, by melting other colours on the surface, sketches of various colours.

That this was the method employed by the ancients is apparent from all the painted windows of the middle ages.

In order to make flashed glass two crucibles are necessary, one containing the red and the other the white glass; the workman first dips his pipe into the red mass and brings up a small globule at the end of it; he then covers this with a proper quantity of white glass. The cylinder which is produced by blowing will exhibit a flashed glass of a beautiful red colour. It is necessary for the purpose of thoroughly uniting the red coating to the plate of white glass, and preventing it from peeling off in the cooling, as happened in Dr. Engelhardt's first attempts, that the composition of white glass should be similar to, if not the same as, that of the red glass, but it is best to make the red glass a little more fusible than the white.

Moreover, the ingredients of the red glass must contain no oxidizing substances. Dr. Engelhardt, who has satisfied himself upon this subject at the glass-houses, proceeds as follows: He places between the large crucibles for the red glass a small crucible, and into this he introduces 4 oz. of protoxide of copper and 1 oz. of protoxide of tin, in addition to the usual ingredients, for every 5 lbs. of the latter, if they happened to contain minium. But if they do not contain minium, he takes 3 oz. of protoxide of copper, and 3 oz. of protoxide of tin for every 2 lbs. of salt which the ingredients contained. If the protoxide of copper is not immediately added to the frit, but is introduced into it afterwards, when the latter is beginning to become clear, a much smaller quantity must be added. For scarlet he uses for every 25 lbs. of frit $\frac{1}{2}$ lb. of protoxide of tin and $1\frac{1}{2}$ oz. of finely levigated protoxide of iron: these are added just at the beginning of the operation.

As soon as the glass has become clear, he mixes with it $1\frac{1}{2}$ oz. of protoxide of copper, and the whole is well stirred up together. Especial care must be taken to avoid bubbles, which are extremely liable to be formed, and specks of sand, as also that the white and the red mass be ready at the same time to admit of their being worked up together.

It is clear from what we have just stated, that to succeed in obtaining a beautiful plate depends very much upon the workman, for the overlaid glass always remains thicker at the mouth of the tube than at the opposite end of the bulb of glass; the plate is therefore always darker on one side than on the other, and only the middle is uniform; indeed the flashing is sometimes so thin at one end, that the colour disappears and passes over into white. Dr. Engelhardt has in his possession several ancient pieces of glass in which this transition from dark to light has been made of the greatest use in producing certain effects; among others, in the satin drapery of a Judith. However, the workman may with some practice acquire the knack of making tolerably uniform plates of glass, and Dr. Engelhardt hopes soon to obtain this result in a glass-house with which he has become connected for this particular purpose.

A frit containing lead seems more likely to preserve the red than any other frit; Herr Engelhardt, however, says that his experiments are not decisive upon this point.

Of the yellow glass.—There are several compounds with which glass may be coloured yellow if they are mixed with it

at the time of its manufacture. Among these are sulphuret of antimony, antimonite of lead, and chloride of silver. The method of colouring with the latter has, in this case, nothing in common with the production of the silver yellow. The employment of chloride of silver, however, requires a very well-refined glass which does not contain an excess of alkali. Without this precaution the chloride would be decomposed, the silver which is in the melted mass of glass, being now reduced to the metallic state, would suffer a rapid agglomeration of its minute particles, and the colour would in consequence disappear. Chloride of silver is not used on account of its being very expensive. Sulphuret of antimony and antimonite of lead are the only colouring materials in general use. But as the yellow which is burnt in gives a fresher and clearer colour, yellow pot-metal is not much manufactured. We merely wish to mention one other yellow here, which is obtained by an admixture of a carboniferous substance with the pot-metal. This imperfect method, which gives a glass of a disagreeable shade of colour and full of small bubbles, has now fallen entirely into disuse.

In order to colour the glass *blue*, black oxide of cobalt is employed, which causes the formation of the protosilicate.

Violet glass is obtained by means of peroxide of manganese with or without an admixture of oxide of cobalt.

A *green* is imparted to glass with oxide of copper, oxide of chromium, or a mixture of antimonite of lead and oxide of cobalt. Oxide of chromium gives a less transparent colour than oxide of copper.

Black glass is prepared from oxide of manganese, oxide of iron, oxide of copper, and oxide of cobalt, in combination with one another. This colour depends upon the mixture of the three colours which are produced by these oxides; that is to say, the mixture of green, blue, and violet, which in proper proportions will give a black.

Finally, glass is made *white* and *opaque* with stannic acid or phosphate of lime, obtained by calcining bones.

Phosphate of lime, or calcined bones, is also used in the manufacture of *opalescent* glass. The exact receipt for the mixture will be given below. Opalescent glass is employed with advantage in every case where the direct rays, or even the reflected light of the sun, is prejudicial to workmen. This, for instance, is the case in the workshops of goldsmiths, jewellers, &c., in government offices, banking-houses, &c., which are situated on the ground floor, where it is often

necessary to use ground glass. So also this glass is of great service for all kinds of lamp-glasses, since the grinding of concave or convex surfaces is attended with difficulty, and makes such glass expensive.

We will now give several receipts for the ingredients of coloured glasses:

Mixture for Rose-coloured Glass

	Parts.
White sand	100
Potash	18
Slaked lime	8
Purple of Cassius	6
Peroxide of manganese	1
Or,	
White sand	100
Minium	78
Caustic potash	35
Nitrate of potash	7
Purple of Cassius	8
Peroxide of manganese	1
Sulphuret of antimony	1

Red Glass.

White sand	100
Minium	60
Caustic potash	30
Nitrate of potash	5
Purple of Cassius	12
Peroxide of manganese	6
Sulphuret of antimony	6

Yellow Glass.

White sand	100
Potash	50
Slaked lime	8
Antimony-yellow, coloured with oxide of lead	6
Or,	
White sand	100
Potash	10
Lime	10
Antimony-yellow, coloured with oxide of lead	10
Or,	
White sand	100
Minium	80
Caustic potash	36
Crystallized nitrate of potash	12
Antimony-yellow, coloured with oxide of lead	8

Blue Glass.

	Parts.
White sand	100
Minium	50
Caustic potash	35
Calcined borax	10
Oxide of cobalt	4
Or,	
White sand	100
Potash	50
Slaked lime	6
Oxide of cobalt	1
Or,	
White sand	100
Minium	80
Caustic potash	40
Nitrate of potash	8
Oxide of cobalt	

Green Glass.

White sand	100
Refined pearlsh	50
Slaked lime	8
Green oxide of chromium	2
Or,	
White sand	100
Refined pearlsh	50
Slaked lime	9
Yellow oxide of antimony	4
Oxide of cobalt, or zaffre	2
Or,	
White sand	100
Minium	75
Calcined potash	38
Nitrate of potash	4
Green oxide of chromium	2
Or,	
White sand	100
Minium	60
White pearlsh	40
Oxide of arsenic	6
Glass of antimony	9
Oxide of cobalt	5

	Parts.		Parts.
Or,		Nitrate of potash	8
Whitewashed sand	100	Oxide of cobalt	8
Minium	85	Peroxide of manganese	8
Calined potash	38	Black oxide of iron	12
Nitrate of potash	8	Oxide of copper	12
Yellow oxide of antimony	1		
Oxide of cobalt	2		
		<i>Opalescent Glass.</i>	
<i>Violet Glass.</i>		White sand	100
White sand	100	Refined pearlash	56
Pearlash	18	Slaked lime	16
Slaked lime	7½	Oxide of silver	3-6
Oxide of manganese	1-10	Phosphate of lime, or calined	
Or,		bones	6
Whitewashed sand	100	Or,	
Minium	78	White sand	100
Calined potash	35	Purified soda	450
Crystallized nitrate of potash	8	Slaked lime	160
Peroxide of manganese	1-2	<i>Caline,* or white broken</i>	
		glass	500
<i>Black Glass.</i>		Hydrochlorate of silver	10
White sand	100	Phosphate of lime from	
White pearlash	66	mutton bones	60
Slaked lime	8	Oxide of arsenic	30
White glass, pulverized	70		
Oxide of arsenic	6	<i>White opaque Glass.</i>	
Oxide of cobalt	10	White sand	100
Peroxide of manganese	10	White pearlash	66
Acetate of iron, or even iron		Slaked lime	8
in the highest state of oxida-		White glass, pulverized	50
tion	5	Oxide of lead	100
Or,		Oxide of arsenic	3
White sand	100	Or,	
Pearlash	18	White sand	100
Lime	6	Calined potash	50
Oxide of cobalt	1	Slaked lime	16
Peroxide of manganese	3	Oxide of tin	60
Oxide of copper	3	Or,	
Black oxide of iron	4	White sand	100
Or,		Minium	78
White sand	100	Calined potash	30
Minium	82	Nitrate of potash, in crystals	8
Calined potash	38	White oxide of tin	62

* A calined mixture of oxide of lead and oxide of tin in the proportion of 4 of the former to 1 of the latter.—(Author's Note)

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